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Co-conveners and committees

Co-Conveners

Olav Sigurd Kjesbu
Institute of Marine Research
Department of Marine Environment
PO Box 1870 Nordnes
N-5817 Bergen, NORWAY
olav.kjesbu@imr.no

Geir Lasse Taranger
Institute of Marine Research
Department of Aquaculture
PO Box 1870 Nordnes
N-5817 Bergen, NORWAY
geirt@imr.no

Edward A. Trippel
Fisheries and Oceans Canada
St. Andrews Biological Station
St. Andrews, New Brunswick
E5B 2L9 CANADA
trippele@mar.dfo-mpo.gc.ca

Scientific Steering Committee

Anne Berit Skiftesvik (Norway)
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Lesley McEvoy (UK)

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Meeting Program

SUNDAY 13 JUNE			
1600-2000	Registration		
2000-2200	Welcome Party		
MONDAY 14 JUNE			
0900-0930	Welcome/Introduction		
		Nepstad, T. Institute of Marine Research	Welcome to Bergen
		Nielsen, NA. ICES	Greetings from ICES
		Nilsen, TC. Vice-major, County of Hordaland	Official opening of the symposium
0930-1000	Keynote I	Rosenlund, G., Skretting, M.	World wide status and perspective on gadoid culture
	Quality, market and economy of cultured gadoids		Lawrence Buckley
1000-1030	Keynote II	Hamnvik, S.	Quality, market and economy of farmed cod
1030-1045	Coffee break		
1045-1100	Oral 1	Nortvedt, R.	A review on quality aspects in Atlantic cod
1100-1115	Oral 2	Luten, J, Kole, A, Heide, M, Østli, J., Schelvis-Smit, R.	Consumer perception of wild and farmed cod and the effects of information about the production type and price
1115-1130	Oral 3	Aas, G.H., Stoknes, I., Økland, H., Synnes, M.	Fish heads - a resource for human consumption and ingredients
1130-1145	Oral 4	Sparboe, LO., Solbakken, J., Windmar, L., Giæver, A, Seiring, J.	Optimal production strategies for juvenile cod, <i>Gadus morhua</i> , in Northern Norway; a production cost analysis
1145-1200	Oral 5	Galloway, T., Alderson, R., Morkemo, H., Mørkøre, T.	Does inclusion of vegetable protein in cod diets affect fillet yield and quality?
1200-1300	Lunch		
	Poster II-1	Kristiansen, HR	Cod (<i>Gadus morhua</i>) meat composition and dietary recommendations
	Poster II-2	Moren, M., Malde, MK., Olsen, RE, Dahl, L., Hemre, G-I, Julshamn K.	Effect of krill meal, high in fluoride on, cod quality and health - necessary assessments of an alternative protein source

	Poster II-3	Mach, D., Nortvedt, R.	The fatty acid contents in the muscle and liver of wild, fed-wild and farmed Atlantic cod (<i>Gadus morhua</i>) and its development of rancidity during storage in ice or in slush.
	Poster II-4	Ahimbisibwe, J. B., Nortvedt, R.	Comparative loss of quality in the Atlantic cod, <i>Gadus morhua</i> , and the Nile perch, <i>Lates niloticus</i> , during ice or slush storage.
	Poster II-5	Smith, S., Espe, M., Nortvedt, R.	Comparative quality study on reared and wild Atlantic cod (<i>Gadus morhua</i>) during storage.
	Genetics and environmental impact of gadoid culture		Josianne Støtterup
1300-1330	Keynote III	Bekkevold, D., Hansen, M.M., Nielsen, EE.	Genetic impact of gadoid mariculture
1330-1345	Oral 6	Jørstad, KE., Karlsen Ø., Svåsand, T., Otterå, H, Holm JC.	Domestication of Atlantic cod, <i>Gadus morhua</i> , - Comparison of genotypic growth under farming conditions
1345-1400	Oral 7	Kolstad, K., Gjerde, B., Refstie, T.	Genetic variation for growth and sexual maturity in Atlantic cod (<i>Gadus morhua</i>)
1400-1415	Oral 8	Delghandi, M., Wesmarjervi, MS., Mortensen, A.	Parental assignment of Atlantic cod (<i>Gadus morhua</i>) - a case study report
1415-1430	Oral 9	Esmark, M.A.	Cod farming - an opportunity to do it right
1430-1445	Oral 10	Hansen, P.K.	Conceptual framework for managing the environmental impact of cod farming
1445-1500	Coffee break		
	Poster III-1	Kovach, A. Berlinsky, D.	Genetic analysis of temporally differentiated spawning populations of Atlantic cod
	Poster III-2	Jørstad, KE., Dahle, G., Rusaas, HE., Otterå, H	Domestication of Atlantic cod, <i>Gadus morhua</i> , - Genetic characterisation of broodstock collected from four Norwegian Coastal cod populations
	Poster III-3	Sarvas, T., Westgaard, J-I., Fevolden, S-E.	Genetic differences among populations of Atlantic cod along the Norwegian coast and the Barents Sea revealed by Pan I and microsatellite loci

	Health and welfare issues		Stewart Johnson
1500-1530	Keynote IV	Bricknell, I., Bowden, T.	Gadoid diseases: What do we know and what do we need to know?
1530-1545	Oral 11	Jensen, I., Mennen, S., Sommer, A-I.	Experimental challenge of Atlantic cod with nodavirus and infectious pancreatic necrosis virus (IPNV)
1545-1600	Oral 12	Brown, LL., Dacanay, A., Bentley, BE., Sarty, D., Johnson, SC.	The response of the immunome of haddock (<i>Melanogrammus aeglefinus</i>) to vaccination
1600-1615	Oral 13	Bergh, Ø., Korsnes, K., Brunvold, L., Sandaal, R-A, Samuelsen, OB.	Bacterial associated with early life stages of cod: 'normal flora' and pathogens
1615-1630	Oral 14	Lund, V., Mikkelsen, H., Børdal, S., Gravningen, K., Schrøder, MB.	Vaccination strategies for farmed Atlantic cod, <i>Gadus morhua</i>
1630-1645	Coffe break		
1645-1700	Oral 15	Gagné, N., Johnson, SC., Cook-Versloot, M., MacKinnon, AM., Olivier, G.	Molecular detection and characterization of nodavirus in several marine fish species from the the north western Atlantic
1700-1715	Oral 16	Samuelsen, OB.	Pharmacokinetics and efficiacy of antibacterials in cod (<i>Gadus morhua</i>). An overview.
1715-1900	Social		
1900-2030	Dinner		
	Poster IV-1	Arnesen, KR., Toften, H., Killie, JE.	Effects of hypoxia on growth, health and risk of vibriosis in juvenile cod
	Poster IV-2	Kettunen A., Delghandi, M, Aasmo Finne, M., Hansen, ØJ., Haug. L., Mortensen, A., Skajaa, K., Wesmarjervi, MS., Fjalestad, KT.	Genetic variation in resistance against vibriosis in Atlantic cod (<i>Gadus morhua</i>)
	Poster IV-3	Reid, H., Birkbeck, TH.	Characterisation of vibrio species in developing cod larvae by DGGE
	Poster IV-4	Pettersen, IH.	Parasites and predators in cod aquaculture
	Poster IV-5	Brunvold, L., Sandaa, R-A, Mikkelsen, H., Welde, E., Bleie, H., Bergh, Ø.	Characterisation of bacterial communities associated with cultured cod larvae by mean of Denaturing Gradient Gel Electrophoreis (DGGE) of PCR-amplified 16S rDNA

	Poster IV-6	Puvanendran, V., Boyce, D., Thorne, L., Wijekoon, M., Brown, JA., Whelan, D.	Juvenile Atlantic cod mortality and health issues: a case study for Newfoundland and Labrador
	Poster IV-7	Myklebust, CF.	The parasite fauna of European hake (<i>Merluccius merluccius</i>) in Western Norway
	Poster IV-8	Vik-Mo, F, Samuelsen, OB., Bergh, Ø.	Efficacy of orally administered flumequine in treatment of vibriosis in Atlantic cod <i>Gadus morhua</i>
	Poster IV-9	Afonso, L.O.B, Leadbeater, S., Gamperl, K., Johnson, S.C, Iwama, G.K.	Physiological stress responses in haddock (<i>Melanogrammus aeglefinus</i>): corticosteroids, plasma glucose and heat shock proteins
	Poster IV-10	Sobecka, E., Wieczaszek, B., Wiepolska, M.	Parasite fauna of the alimentary tract and the biochemical parameters of liver and muscles of cod, <i>Gadus morhua</i> , from three different locations
2030-2200	Poster session with bar		
TUESDAY 15 JUNE			
	Early feeding and nutrition		Lesley McEvoy
0900-0930	Keynote V	Hamre, K.	Nutrition in cod (<i>Gadus morhua</i>) larvae and juveniles
0930-0945	Oral 17	Barr, Y., Helland, S.	Improvement of live fish food nutritional quality
0945-1000	Oral 18	Kvåle, A., Mangor- Jensen, A., Hamre, K.	Hydrolysed proteins seems to be advantageous for cod (<i>Gadus morhua</i>) larvae
1000-1015	Oral 19	van der Meeren, T., Olsen RE., Fyhn, HJ., Hamre, K.	Biochemical composition of copepods for evaluation of feed quality in juvenile production of marine fish
1015-1030	Oral 20	Wold, P-A., Kjørsvik, E., Hoehne-Reitan, K., Øie, G., Draget, K.I.	Acceptance of a formulated moist diet based on copepods in early weaning of Atlantic cod (<i>Gadus morhua</i>) larvae - a pilot study
1030-1045	Coffee break		
1045-1100	Oral 21	Tonheim, SK., Espe, M., Rønnestad, I.	Pre-hydrolysis improved the utilisation efficiency of a model protein tube fed to stomach-less fish larvae
1100-1115	Oral 22	King, N., O'Brien, E., Ceulemans, S., D'Hert, P., Manchester, E.	An evaluation of INVE post-weaning and nursery diets for the commercial culture of cod

1115-1130	Oral 23	Opstad, I., Saomi, J. Olsen RE.	Weaning of Atlantic cod (<i>Gadus morhua</i>) with microparticulate diets made of alternative protein sources
1130-1145	Oral 24	Albrektsen, S. Hope, B., Aksnes, A.	Growth, feed efficiency and digestibility in Atlantic cod (<i>Gadus morhua</i>) fed two different fish meal qualities and three dietary levels of vegetable proteins
1145-1200	Oral 25	Aas, K., Siikavuopio, SI.	Growth and feed intake in juvenile cod (<i>Gadus morhua</i> L.) fed continuously or during light or dark hours
1200-1300	Lunch		
1300-2000	Tour to Austevoll		
2000-2130	Dinner		
2130-	Social		
	Poster V-1	Porter, SM., Bailey, KM.	Some factors affecting the early feeding success of walleye pollock (<i>Theragra chalcogramma</i>) larvae
	Poster V-2	<i>Withdrawn</i>	
	Poster V-3	Kling, LJ., Muscato, J., Jordaan, A.	Growth, survival and feed conversion efficiency of post-metamorphosed Atlantic cod (<i>Gadus morhua</i>) reared at different temperatures
	Poster V-4	Cutts, C., Sawanboonchun, J., Mazorra de Quero, C., Bell, JG.	Essential fatty acid dynamics and larval performance in cod (<i>Gadus morhua</i>)
	Poster V-5	Gonzalez-Vecino, JL., Cutts, CJ., Batty, RS., Greenhaff, PL., Wadsworth, S.	The effects of nucleotide-enriched broodstock diet on first feeding success and survival of haddock (<i>Melanogrammus aeglefinus</i> L.) larvae
	Poster V-6	Karlsen, S., Strand HK., Falk-Petersen, I-B.	Effects of including liposomes and enzymes in formulated start feed for cod larvae
	Poster V-7	Park, HG., Puvanendran, V., Kellett, A., Parrish, CC., Brown, JA.	Effect of enriched rotifers on the growth and survival of Atlantic cod (<i>Gadus morhua</i>) larvae
	Poster V-8	Garatun-Tjeldstø, O., Otterå, H., Julshamn, K., Austreng, E.	Feed ingestion estimated in juvenile cod by inert lanthanide markers - preference and availability of feed particle sizes
	Poster V-9	Korsnes, K., Nicolaisen, O., Bergh, Ø., Skår, C., Nerland, A.	Bacteria in the gut of juvenile cod fed rotifers enriched with four different commercial diets

	Poster V-10	Alver, M., Tennøy, T., Øie, G., Alfredsen, JA.	Investigation of live feed dynamics in cod (<i>Gadus morhua</i>) larvae tanks using an automatic plankton counter
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WEDNESDAY 16 JUNE			
	Early development, behaviour and juvenile rearing		Anne Berit Skiftesvik
0900-0930	Keynote VI	Brown, J., Puvanendran, V., O'Brien-MacDonaldland, K., Marcil, J.	Quantity or quality? Tweaking the production of Atlantic cod
0930-0945	Oral 26	Tanem, I., Kjørsvik, E. Galloway, TF.	Positive correlations between egg dry weight, larval size and muscle growth in Atlantic cod
0945-1000	Oral 27	Browman, HI., St-Pierre, J-F., Skiftesvik, AB., Racca, RG.	Behaviour of Atlantic cod (<i>Gadus morhua</i>) larvae: an attempt to link maternal conditions with larval quality
1000-1015	Oral 28	Yacoob, SY., Browman, HI, Jensen, PA	Olfactory sensitivity of juvenile cod to amino acids
1015-1030	Oral 29	Salvanes, A.G.V., Braithwaite, VA.	Differences in spatial landscape in nursery habitats and asymmetries in aggressive interactions in hatchery reared North Sea cod
1030-1045	Coffe break		
1045-1100	Oral 30	Björnsson, B., Ólafsdóttir, SR.	Effects of water quality and stocking density on growth rate, nutritional condition and mortality of juvenile cod (<i>Gadus morhua</i> L.)
1100-1115	Oral 31	McCollum A., Geubtner J., Hunt von Herbing, I.	Temperature effects on the metabolic cost of growth in developing Atlantic cod, <i>Gadus morhua</i>
1115-1130	Oral 32	Peck, M.A., Buckley, L.J., Bengtson, D.A., Temming, A.	Effects of temperature, body size and feeding level on the growth bioenergetics of young juvenile cod (<i>Gadus morhua</i>) and haddock (<i>Melanogrammus aeglefinus</i>)
1130-1145	Oral 33	Smith, K., Brown, J.	Weight gain and lipid deposition in juvenile Atlantic cod <i>Gadus morhua</i> , during compensatory growth
1145-1200	Oral 34	Herlin, M., Telfer, T. Roy, W.	Nitrogen retention of farmed Atlantic cod <i>Gadus morhua</i> fed on a commercial diet
1200-1300	Lunch		
	Poster VI-1	Braithwaite, VA., Salvanes, A.G.V.	The importance of environmental variability for North Sea cod reared for restocking

	Poster VI-2	Siikavuopio, S.I., Sæther, B-S., Foss, A.	Effects of chronic ammonia exposure on growth in juvenile Atlantic cod
	Poster VI-3	Monk, J., Puvanendran, V., Brown, JA.	The effects of varying light intensities on growth and survival of Atlantic cod (<i>Gadus morhua</i>) larvae
	Poster VI-4	Falk-Petersen, I-B.	Differentiation of tissues and organs of cod larvae
	Poster VI-5	Knauf, I., Trippel, EA., Burrige, LE., Neil SRE.	Behavioural and physiological processes of juvenile haddock (<i>Melanogrammus aeglefinus</i>) at continuous light and natural photoperiod
	Poster VI-6	Buckley, L.J. Davies, E.J.	Optimum photoperiod for survival and growth of larval cod (<i>Gadus morhua</i>)
	Poster VI-7	Skajaa, K., Toften, H.	The effect of supersaturated water on growth and survival in juvenile cod
	Poster VI-8	<i>Withdrawn</i>	
	Poster VI-9	Makhotin, V, Foss, VH., Agnalt, A-L., Meier, S., Otterå, H.	Study of malformation and mortality in cod eggs from spawning stock collected from 4 Norwegian fjords (Porsanger fjord, Tysfjord, Helgeland and Øygarden)
	Poster VI-10	Geffen, AJ., Fox, CJ., Nash, RDM.	Factors influencing temperature dependent development rates of cod (<i>Gadus morhua</i> L.) eggs
	<i>On-growth and rearing technology</i>		<i>Håkon Otterå</i>
1300-1330	Keynote VII	Karlsen, Ø., Dahle, R., Norberg, B., Kjesbu, O.S., Taranger, G.L.	Effects of feeding regimes and light treatments on age at puberty in farmed Atlantic cod
1330-1345	Oral 35	Norberg, B. Karlsen, Ø., Taranger, GL., Kjesbu, OS.	Cod puberty - age at first maturation in relation to seasonal growth and energy acquisition during the first year of life
1345-1400	Oral 36	Davie, A., Migaud, H., Mazorra, C., Porter, M., Treasurer, J., Bromage, N	Photoperiod control of maturation and growth in gadoids: an essential tool for commercial culture
1400-1415	Oral 37	Taranger, GL, Migaud, H., Kjesbu, OS., Aardal, L., Hansen, T.	Effect of different photoperiods and light intensities on puberty and melatonin profiles in cod
1415-1430	Oral 38	Alderson, R. and Galloway, TF.	Growth rate variation and growth prediction in cultivated Atlantic cod
1430-1445	Oral 39	Treasurer, J., Sveier, H.	Growth, survival, diet and on-growing husbandry of haddock <i>Melanogrammus aeglefinus</i> in tanks and sea cages in Scotland

1445-1500	Oral 40	Watson, JT., Sales, S., Cumming, G., Fitzsimmons, SD, Walden, J., Arthur, G., Saravanan, S., McEvoy, LA.	Comparison of performance of two size groups of farmed cod juveniles following transfer to sea
1500-1530	Coffe break		
	Poster VII-1	Opstad, I., Raae, AJ.	Effects of water movement on survival and growth of eggs and newly hatched larvae of cod and halibut
	Poster VII-2	Kristoffersen, C., Karlsten, Ø., Schulz, RW., Migaud, H., Stefansson, SO., Taranger, GL.	Use of continuous light to delay puberty in farmed Atlantic cod
	Poster VII-3	Hansen, A-C., Tveit, K., Rosenlund, G., Karlsten, Ø., Hemre, G-I.	Effects of replacing fish meal with two vegetable protein resources (soybean and corn gluten meal) in diets for Atlantic cod (<i>Gadus morhua</i>)
	Poster VII-4	Moe, H., Fredheim, A., Heide, MA., Sunde, LM.	New net pen technology to prevent escape of cod in the on-going phase
	Poster VII-5	Howell, WH., Chambers, MJ.	Cod and haddock production in submerged cages off the coast of New Hampshire, USA
	Biotechnology and reproduction		Birgitta Norberg
1530-1600	Keynote VIII	Goetz, F., Norberg, B.	Using global genome approaches to address problems in cod mariculture
1600-1615	Oral 41	Nerland, A.	CodGen - mapping of the genome of Atlantic cod at a molecular level
1615-1630	Oral 42	Puvanendran V., Kellet, A., Brown, JA.	Growth and survival of Atlantic cod larvae from four latitudinally separated populations: implications for broodstock development
1630-1645	Oral 43	Clemmesen, C., Buehler, V., Carvalho, G., Case, R., Hauser, L., Hutchinson, W., Kjesbu, O.S., Moksness, E., Otterå, H., Paulsen, H., Thorsen, A., Willert B., Svåsand, T.	Are differences in short-term and long-term growth and nutritional condition estimates of larval and juvenile cod related to maternal effects?
1645-1700	Oral 44	Hansen. LA., Damsgård, B., Delghandi M.	Spawning behaviour and reproductive success in cod, <i>Gadus morhua</i> L.

1730-1745	Oral 45	Probst, WN., Trippel, EA., Rideout, RM., Kraus, G.	Parental effects on early life history traits of haddock, <i>Melanogrammus aeglefinus</i>
1715-1730	Oral 46	Trippel, EA., O'Reilly, P.T., Rideout, R.M., Neil, S.R.E., Hamilton, L.C., Kenchington, E., Herbinger, C.M., Taggart, C.T.	Genetic variation and spawning performance among related and unrelated second generation aquaculture broodstock of haddock (<i>Melanogrammus aeglefinus</i>)
1745-1800	Oral 47	Witthames, P.R., Thorsen, A., Kjesbu, OS.	Regulation of cod (<i>Gadus morhua</i>) realised fecundity in constant and natural photoperiod regimes
	Poster VIII-1	Anokhina V.	Dynamics of maturation and spawning of Northeast Arctic cod, <i>Gadus morhua</i> , in sea cages at the Barents sea coast of Russia
	Poster VIII-2	Titov, O., Mukhina, N.	Cod (<i>Gadus morhua kildensis</i> Derjugin) from the Mogilnoe lake: life cycle and living conditions. Applications to mariculture
	Poster VIII-3	DeGraaf, JD., Smith, NG., Berlinsky DL.	Cryopreservation and computer-assisted motility assessment of Atlantic cod (<i>Gadus morhua</i>) spermatozoa
	Poster VIII-4	Rideout, RM., Trippel, EA., Litvak, MK.	The development of haddock and Atlantic cod sperm cryopreservation techniques and the effects of sperm age on cryopreservation success
	Poster VIII-5	Wiecaszek, B, Antoszek, A.	Results of preliminary studies on the taxonomical status of cod stocks in the southwestern Baltic at Polish coasts
	Poster VIII-6	Tveiten, H., Frantzen, M.	Steroid synthesis in ovarian tissue of Atlantic cod <i>in vitro</i>
	Poster VIII-7	Pickova, J.	Antioxidants in cod roe of wild origin from Baltic and Western populations
	Poster VIII-8	Buehler, V., Carvalho, G., Case, R., Clemmesen, C., Hauser, L., Hutchinson, W., Kjesbu, OS, Moksness, E., Otterå, H., Paulsen, H., Thorsen, A., Svåsand, T.	Influence of maternal effects on cod inferred by the otolith microstructure analysis
	Poster VIII-9	Otterå, H., Agnalt, A-L., Jørstad, K.	Spawning cycle of captive cod from four regions in Norway

1745-1800	Closing remarks	Ed Trippel	
1800-2000	Social		
2000-2230	Conference dinner		
		Solemdal, P.	1) A scientific innovation open up for new practise that leads to profound transformation of vision concerning fluctuations of fisheries 2) Small talks from the childhood of marine aquaculture
THURSDAY 17 JUNE			
	Optional post-Symposium tour to visit a commercial farm		

Keynote I

WORLDWIDE STATUS AND PERSPECTIVE ON GADOID CULTURE

Grethe Rosenlund¹ and Magnus Skretting²
1 Nutreco Aquaculture Research Centre AS
2 Nutreco Cold Water Species
E-mail address: grethe.rosenlund@nutreco.com

Successful culture of salmonids over a couple of decades led to increasing interest for diversification into culture of other species during the 1980's. Nurtured by declining fisheries, emphasis was put on developing Atlantic cod (*Gadus mohua*) as a new species for aquaculture. However, recovery in fisheries showed that significant culture of gadoids was premature at that stage. After ten years where gadoid culture was synonymous with maintenance R&D activities, cultivation of gadoids has gained new interest in recent years. Atlantic cod is presently the main species targeted for commercial culture, and activities are concentrated around the North Atlantic. In addition closed cycles have been established for haddock (*Melanogrammus aeglefinus*) and pollack (*Pollachius pollachius*), but production of these species (in Canada and Spain, respectively) is rather modest. In a short to medium term perspective, Atlantic cod will be the dominant species in gadoid culture and it is believed that it can reach levels similar to those of farmed salmon within the next 15-20 years. This development can take place because methods for year around production of juveniles as well as significant hatchery capacity have been established. Although hampered by production failures and sub-optimal juvenile quality, the evolution follows a similar path to that seen for bass and bream hatchery techniques during the 1990's. Also, there is an industry pull for farmed cod to fill the gap between the market needs and the supply from fisheries. However, challenges exist for cod farming to be successful as predicted. Juvenile production must be put on a more reproducible footing with respect to survival and quality. For the on-growing phase supply of safe and cost-efficient feeds produced from sustainable raw materials is of utmost importance. Other key words in this context are disease management, fish quality and product and market development.

Keynote II

QUALITY, MARKET AND ECONOMY OF FARMED COD

Siri Hamnvik,
Marketing Manager New Species
Norwegian Seafood Export Council (NSEC)
E-mail address: Siri.Hamnevik@seafood.no

Global catches of wild cod have fallen dramatically the last 30 years. This decline has not been the result of lower interest in the species from consumers and key buyers. The different qualitative and quantitative analysis conducted by NSEC and The Norwegian Institute of Fisheries and Aquaculture Research show clearly that cod has a strong position with European chefs and consumers, and is well placed in the European diet. Key buyers create a market pull for a high quality farmed whitefish, delivered fresh, to fill the gap between the market needs for fresh fish and the supplies from fisheries. Due to the strong position of cod in the mind of the consumers, Atlantic cod remains the favourite species. Especially since the fish is considered suitable for both gourmet and everyday cooking and then give a potential for becoming a volume product. Challenges exist for farmed fish in general to be accepted in some upper segments of the market, give limitations on the potential for upward pricing for farmed cod. Market studies show that the dominant perception among chefs and consumers is that wild generally is a better and more natural product than farmed. However, recent market tests in Norway, England and Spain, show that the quality of farmed cod produced under different feeding regimes is considered very high among chefs. Especially the freshness of the product is considered superior, indicating a potential for a favourable market reception. However, as a major difference from when the salmon industry was developed, farmed cod has to find its place and develop the markets alongside large volumes of wild gadoid species including cod. Another challenge somewhere in the distant future could be that high growth rates achieved by the pioneering companies is likely to trigger competition. The fear of an imbalance between the development rate of production and market development exists, resulting in falling prices for both farmed and wild gadoid products. The potential exists for a very high yearly growth rate in the early stages of this development. As with farmed salmon it can be expected a trend of falling prices with reduction in costs.

Keynote III

GENETIC IMPACT OF GADOID MARICULTURE

Dorte Bekkevold, Michael M Hansen and Einar E Nielsen
Danish Institute for Fisheries Research, Population Genetic Laboratory, Department of Inland Fisheries
Vejlsvøvej 3, 98600 Silkeborg, Denmark
E-mail address: db@dfu.min.dk

Large scale production of gadoids in culture may have large genetic and ecological effects on wild populations. Lessons from salmonid farming and supplemental stocking point to a number of potential problems, but also to ways of minimising adverse effects of gadoid mariculture. In salmonids, both selection for specific traits and the inadvertent effects of hatchery rearing leading to domestication selection have been shown to alter the genetic composition of individuals compared to that of wild fish. Several recent studies have documented genetic and ecological effects of farmed fish introduced into local wild populations. Escapes or releases of reared fish are also associated with increased straying behaviour, and farmed fish may therefore have an effect on wild populations not just locally, but also regionally. Recently, genetic studies have shown that gadoids are subdivided into genetically differentiated populations and that reproductive isolation may occur over geographically small scales. Such patterns are likely to also reflect adaptations to local conditions, exacerbating the concern that fitness and recruitment in local populations may be adversely affected by introgression from reared individuals. Estimates of ecological and genetic impact of farmed fish on wild populations will be reviewed and perspectives to gadoid ecology are discussed in relation to the potential impact of large-scale mariculture.

Keynote IV

GADOID DISEASES: WHAT DO WE KNOW AND WHAT DO WE NEED TO KNOW?

Ian Bricknell and Tim Bowden
FRS Marine Laboratory, Aquaculture and Aquatic Animal Health, 375 Victoria Road, Torry, Aberdeen
AB11 9DB, UK
E-mail address: i.r.bricknell@marlab.ac.uk

As new aquaculture species emerge the opportunity for pathogens to meet a new host increases. This gives two possible scenarios. Firstly, if a species is co-cultured with a second species asymptotically carrying a disease to which the first is susceptible, a serious clinical outbreak may occur. Secondly, in environments with a high infective pressure, such as fish farms, a pathogen may cross the species barrier, often with serious consequences for the new host. As gadoids become more widely cultured the potential for them to be exposed to established aquaculture disease, particularly from salmonids, increases, as does the likelihood that unique gadoid diseases will emerge. The current literature identifies several potential diseases that may interact between farmed fish and their wild counterparts. These include Viral Haemorrhagic Septicaemia Virus (VHSV; has been found in wild gadoids), Infectious Pancreatic Necrosis Virus (IPNV; common in farmed salmonids), *Aeromonas salmonicida* and *Vibrio anguillarum* (two bacterial diseases frequently isolated from salmonids and gadoids). If the issue of disease interactions between species is considered for Atlantic salmon, haddock and cod, then any of the following scenarios are possible. It has been established that Atlantic haddock and cod are more resistant to *Aeromonas salmonicida* and IPNV than Atlantic salmon, but more susceptible to *Vibrio anguillarum* and VHSV than Atlantic salmon. *Aeromonas salmonicida* and *Vibrio anguillarum* may be controlled by vaccination, using commercially available vaccines originally developed for use in salmonids. However, there are currently no fish viral vaccines licensed in the UK. The sea louse, *Caligus elongatus*, is known to infect all three species considered here, but conversely the salmon louse (*L. salmonis*) only infects Atlantic salmon and poses a minimal risk to cultured Atlantic cod and haddock, although recent work in the author's laboratory has suggested that adult *L. salmonis* may use gadoids as a "lifeboat" host under periods of severe environmental stress. This plenary paper will examine the state of our knowledge and identify areas that require urgent research.

Keynote V

NUTRITION IN COD (*GADUS MORHUA*) LARVAE AND JUVENILES

Kristin Hamre

National Institute of Nutrition and Seafood Research (NIFES), Bergen, Norway.

E-mail address: kristin.hamre@nifes.no

During the past few years, the capacity for cod juvenile production in Norway has increased from a few 100 000 to 70 million per year. The actual production is increasing steadily, but malformations in larvae and juveniles increase production costs and constitutes an ethical problem. The malformations may partly be nutrition dependent, since larvae fed copepods in semi-extensive systems usually develop normally. To identify nutrients that may be deficient or in excess in live feed, we are in the process of screening the nutrient composition of rotifers and *Artemia* grown and enriched on different feeds. Experiments will be performed to enrich the live feed with nutrients that are deficient. A goal in marine larval culture is to replace live food with formulated diets as early as possible. It is important that these diets contain protein which is available for the larvae and phospholipids that promote the absorption and transport of fat. The optimum macronutrient composition in diets for cod juveniles has been determined and may, with caution, be extrapolated to the larval stage. A problem in using formulated diets on the larval stage is the extensive leakage of nutrients due to the high surface area to volume ratios of the microparticles. The leakage leads to loss of small water-soluble molecules such as vitamins, minerals and free amino acids, but extensive leakage of water-soluble protein has also been shown. The demand for protein that is available for the larvae, which probably is equivalent with water-soluble protein, is therefore in conflict with the need to reduce protein leakage from the feed. Development of feed production technology to prevent nutrient leakage is necessary in order to make formulated diets a good alternative to live feed.

Keynote VI

QUANTITY OR QUALITY? TWEAKING THE PRODUCTION OF ATLANTIC COD

Joseph Brown¹, V. Puvanendran¹, Kelly O'Brien-MacDonald¹ and Julie Marcil²

¹ Ocean Sciences Centre, Memorial University of Newfoundland, St. John's, NL Canada A1C 5S7;

² Department of Biology, Dalhousie University, Halifax, N.S. Canada

E-mail address: jbrown@mun.ca

The culture of Atlantic cod (*Gadus morhua*) has proceeded at a frantic pace in countries bordering the North Atlantic. In this talk we will address two challenges to the consistent production of large numbers of juveniles. One issue that could affect efforts along the east coast of North America are observed differences in the behaviour, growth, and survival of larvae from separate populations cultured in "common environments". These results, along with observed differences in the "shape" of juveniles, suggest that broodstock selection will be important as adult fish may be locally adapted (i.e., water temperature) to the different areas. A second issue is hatchery production. For the most part, good success has been achieved in the hatchery production of juveniles. Most hatcheries report good growth during this stage of production. However, mortality increases during metamorphosis, grading and weaning and this may relate to the quality (robustness) of the larvae. In order to improve larval quality, we are focussing efforts on the foraging environment and on the digestive physiology of the larvae. In order to improve feeding success, we have begun to examine certain husbandry practices used during production which influence growth, survival and quality. In addition to examining how the external environment influences production, we are also looking at the development of the digestive physiology of the larvae to determine what they are capable of digesting and how this varies with the quality of the live feed.

Keynote VII

EFFECTS OF FEEDING REGIMES AND LIGHT TREATMENTS ON AGE AT PUBERTY IN FARMED ATLANTIC COD

Ørjan Karlsen¹, Roy Dahle¹, Birgitta Norberg¹, Olav S. Kjesbu² and Geir Lasse Taranger²

¹ Institute of Marine Research, Austevoll, N-5392 Storebø, Norway

² Institute of Marine Research, PO Boc 1870 Nordnes, N-5817 Bergen, Norway

E-mail address: orjan.karlsen@imr.no

Sexual maturity in Atlantic cod results in loss of appetite and weight during spawning, leading to increased production time, higher mortality and reduced food conversion efficiency. Normally, all farmed cod in western Norway spawns in their second spring after hatch, with a mean weight less than marketable size. The spawning results in the mean weight in June after spawning being comparable with the weight in January, just prior to spawning. Even though Atlantic cod display a compensatory growth spurt after spawning, it will not fully compensate for the effects of spawning. Thus, unless the gonads are sold as a separate product, methods to delay maturation until the cod reach marketable size are strongly needed. The current paper reviews a series of studies with different feeding history and photoperiod treatment on age at puberty in cod. Restricted feeding can have an effect on age at puberty, but at the cost of dramatically reduced growth. Continuous light (LL) treatment affects the strongly photoperiod dependent maturation cycle. Indoor trials with LL treatment have delayed puberty with at least one year. In contrast, use of LL in sea cages appears to be less effective in delaying puberty, and normally, spawning is delayed by 4-6 months in cages. Resent trials indicates that LL treatment with higher intensity are more effective id delaying puberty in outdoor tanks. LL treatment may also have an effect on growth independent of maturation, particularly during the winter period. All year juvenile production implies that cod with very unequal photoperiod history will be transferred to sea cages at different times of the year, and effects this light history has on age of puberty are not well known.

Keynote VIII

USING GLOBAL GENOME APPROACHES TO ADDRESS PROBLEMS IN COD MARICULTURE

Frederick Goetz¹, Birgitta Norberg²

¹ Great Lakes WATER Institute, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin, U.S.

² Institute of Marine Research, Austevoll Aquaculture Research Station, N-5392 Storebø, Norway

E-mail address: rgoetz@mbl.edu

A number of techniques including expressed sequence tag analysis (EST), serial analysis of gene expression (SAGE), and microarrays are available to study the global expression and regulation of genes. Many of these techniques are being used for intensively reared fish such as trout, salmon and catfish to study genes involved in growth, reproduction and health. In contrast, relatively little is known about the composition and regulation of transcriptomes (expressed genes) in gadids. However, several bottlenecks in cod mariculture (e.g., early gonadal maturation and health/stress) might benefit from the discovery and analysis of genes involved in reproduction, growth and disease. As a result, we have begun EST analysis of genes in the cod ovary at various reproductive stages, and in hematopoietic cells stimulated with molecules such as lipopolysaccharides. Complimentary DNA (cDNA) libraries of cod ovaries taken at late vitellogenesis, spawning (i.e., during oocyte maturation and ovulation), and from spent females have been constructed, and nearly 1,000 ESTs have been analyzed from these libraries. As expected, a number of ovarian related genes were observed including various zona pellucida egg membrane proteins. However, a number of pivotal cell cycle (mitotic and meiotic) regulators were also identified including cyclins B1, B2, A1, A2, and G1, and also genes involved in the regulation of apoptosis such as the Bcl-2-related ovarian killer protein (Bok). The appearance of so many of these regulators is particularly interesting given the multiple spawnings that occur in cod. Finally, a cDNA for a novel cod antifreeze protein was also observed a number of times, suggesting the existence of a cod egg-specific antifreeze protein. The potential benefits of global genome projects such as the ovarian EST analysis, and how these techniques could be used to enhance gadid mariculture will be discussed.

Oral 1

A REVIEW ON QUALITY ASPECTS IN ATLANTIC COD

Ragnar Nortvedt
NIFES - National Institute of Nutrition and Seafood Research
POB 176 Sentrum, 5804 Bergen, Norway
and
Department of Biology, UoB, High Technology Center, 5020 Bergen, Norway
E-mail address: ragnar.nortvedt@nifes.no

A bibliography review focusing on quality aspects in Atlantic cod (*Gadus morhua*) has been based on approx. 2.500 international papers, Norwegian reports and university theses. The dominant knowledge from this literature collection stems from investigations on wild cod in the period 1950 - 1980 and should serve as an important guideline and source for comparison with the quality work on farmed cod in the future. The literature from the last decade is focusing more on farmed cod and several studies have lately carried out direct comparisons of quality in wild, wild fed and farmed Atlantic cod. The present paper summarize the quality aspects of crude and biochemical composition, the life cycle aspect, the effects of feeding and starving, the slaughtering procedures and storage and finally the documented methods for quality evaluation of Atlantic cod. Based on a range of documented and expected variation in quality parameters the paper conclude with a suggested industrial standard for quality of Atlantic cod.

Oral 2

CONSUMER PERCEPTION OF WILD AND FARMED COD AND THE EFFECT OF INFORMATION ABOUT THE PRODUCTION TYPE AND PRICE

Joop Luten¹, Adriaan Kole², Morten Heide¹, Jens Østli¹ and Rian Schelvis-Smit².
¹Norwegian Institute of Fisheries and Aquaculture Research (Fiskeriforskning),
Muninbakken 9-13, POBox 6122, Tromsø, Norway
²Netherlands Institute for Fisheries Research, POBox68, 1976CA IJmuiden, The Netherlands
E-mail address: joop.luten@fiskeriforskning.no

A successful farming of cod could bring a new reality to the consumers' everyday life: If you want to buy cod, you could be forced to choose between farmed and wild cod because they will be present in the supermarket at the same time. How will the consumers react to this situation? In collaboration between the Netherlands Institute for Fisheries Research and Fiskeriforskning of Norway an in-house study using fresh pre-packed filet of cod was set up. One of the main objectives was to study expectations and perceptions related to fresh cod by varying the labelling/information on the packs. The wild cod was supplied from Iceland and the farmed cod from Norway (no information about country-of-origin was given to the consumers). 1440 consumers in the Dutch TasteNet consumer panel participated and they all received products of fresh cod to be assessed in their normal household situation. Their expectations (by just looking at the product and reading the label/information) were recorded, likewise their perception after consumption. Packs with no information, except for containing cod were included as a control in this study. The main effects were observed for information about product type (farmed versus wild) and for price (high price versus low price). When the consumers received information of production type wild cod was evaluated more favourably than farmed cod. Higher priced cod was rated more favourable than the lower priced cod. These results indicate that the "cod segment" could face both opportunities and challenges in the market place and on-going analyses using segmentation techniques will break the general results into consumer segments to better understand how these perceptions/expectations are spread. The results of these studies will be included in the presentation.

Oral 3

FISH HEADS - A RESOURCE FOR HUMAN CONSUMPTION AND INGREDIENTS

Grete Hansen Aas, Iren Stoknes, Hege Økland, Marianne Synnes
P. Box 6122, NO-9291 Tromsø
E-mail address: grete@mfaa.no

Most of the fish-heads are today being minced for animal feed. To improve utilisation of fish-heads, Møre Research has characterised fish-heads from different species. Large heads from cod contained a lot of muscle-meat that may be processed into consumption products like tongues, cheeks, and "medallions". In addition to the muscle meat in tongues and cheeks, the lean fish-heads were rich in proteins, collagen, and minerals. The fatty acid and lipid class composition of the eyes and brain were determined for several species like Atlantic Cod (*Gadus morhua*), Saithe (*Pollachius virens*), Atlantic Salmon (*Salmo salar*). The lipid content of the eyes reflected the lipid content of fish-muscle. The lean species contained high ratios of docosahexaenoic acid (DHA) versus eicosapentaenoic acid (EPA) and high ratios of n-3 fatty acids versus n-6 fatty acids, while these ratios were significantly lower for the fat fish-species. The major lipid class in eyes of lean species was phospholipids, while triacylglycerols was the dominant lipid class in eyes of fat species. Chemical analysis of whole heads and part of heads like eyes, brains and gills were analysed. Fatty acid composition in eyes and brains of several lean and fatty species has been examined. There was found as much as 38% DHA in total fat from some of the tissues. It has also been focused on skin and bones from fish heads as a source for collagen and gelatine. Content of hydroxyproline has been analysed and collagen has been extracted by use of a laboratory method. Protein-hydrolysates from whole heads have been made by an enzymatic process. Freeze-drying has been used in order to transfer the hydrolysates into powders.

Oral 4

OPTIMAL PRODUCTION STRATEGIES FOR JUVENILE COD, GADUS MORHUA, IN NORTHERN NORWAY; A PRODUCTION COST ANALYSIS

Lars Olav Sparboe, Jostein Solbakken, Lars Windmar, Anton Giæver, Jan Seiring
Akvaplan-niva AS, Polarmiljøseneteret, 9296 Tromsø, Norway
E-mail address: js@akvaplan.niva.no

During the last 3 years, there has been a strong focus on establishing industrial larval rearing as a basis for a big cod farming industry in Norway. The planned capacity for the 16 hatcheries is about 65 mill. cod juveniles of 2-5g. At least in northern Norway, these juveniles are too small to stock into sea cages. The ultimate goal of the project is to investigate which of the different production strategies for juvenile cod (1g-300g) that gives the highest profitability within the constraints given by the geographical structure and number of hatcheries and on-growing farms, different sea temperatures along the Norwegian coast and the best available biological and technological knowledge from the literature and operational cod farmers. The collected and structured information will act as assumptions for an analysis that will define the most optimal production strategies at chosen sites along the coast of northern Norway. At the end, the defined production strategies will be analyzed by in-depth analysis of the production cost that will show how key cost parameters and site-specific factors and changes in these will influence the overall profitability. Results will be presented at the conference.

Oral 5

DOES INCLUSION OF VEGETABLE PROTEIN IN COD DIETS AFFECT FILLET YIELD AND QUALITY?

Trina F. Galloway¹, Richard Alderson², Hanne Morkemo³ and Turid Mørkøre³
1 BioMar AS, Kjøpmannsgt. 50, 7484 Trondheim, Norway
2 BioMar Ltd, North Shore Rd, Grangemouth FK3 8UL, Scotland
3 Institute of Aquaculture Research (AKVAFORSK), 1430 Ås, Norway
E-mail address: trine.galloway@biomar.no

Atlantic cod (*Gadus morhua* L.) require high dietary protein levels. Cod farming requires low feed prices if it is to be economically successful, and one approach to achieving this is by replacing some dietary fish meal with vegetable protein raw materials. However, it is important to know how this affects the quantity and quality of the fillet. The present study evaluated harvest yield and fillet quality in farmed cod fed 5 diets in which up to 25% of the protein came from vegetable protein sources. The mean start weight was 450g and the cod grew to 800-900g in 4 months. At the end of the trial the fish were measured for length, weighed and filleted and the liver and fillet weights were recorded. More than 20 fillet sensory quality traits were evaluated by a professional taste panel. pH, dry matter and texture of raw and cooked fillets and fillet colour were measured in the same fillets. There were no significant differences between treatments in growth or feed conversion rate during the trial. Hepatosomatic index (HSI) and fillet yield were slightly lower in the fish fed diets containing vegetable protein than in cod fed a fish meal based diet. No fillet sensory quality traits were affected by dietary treatment, except flaking of the fillet which varied between treatments. pH, dry matter and texture of raw and cooked fillets and fillet colour also varied between treatments, but there were no trends in relation to dietary raw materials used. The conclusions of the present study are that good growth, feed conversion and fillet quality can be achieved when up to 25% of the protein in diets for farmed cod comes from vegetable protein sources. However, HSI and fillet yield are slightly reduced in fish fed diets containing vegetable protein.

Oral 6

DOMESTICATION OF ATLANTIC COD, *GADUS MORHUA*, - COMPARISON OF GENOTYPIC GROWTH UNDER FARMING CONDITIONS

Jørstad, K.E.*, Karlsen, Ø., Svåsand, T., Otterå, H. and Holm, J.C.
Institute of Marine Research, Department of Aquaculture, Bergen, Norway
*Corresponding author K.E. Jørstad
Address: Post Box 1870 Nordnes, 5817 Bergen, NORWAY
E-mail: knut.joerstad@imr.no

The aquaculture industry in Norway is now developing sustainable farming of the Atlantic cod, *Gadus morhua*. Extensive research, including cod farming trials and cod stock enhancement, have been carried out for this species in Norway during the two last decades. The success of domestication of new species is dependent of the genetic variability in the wild broodstock and adaptation of genotypes to the farming environment. Genetic analyses of cod experiments under farming conditions were incorporated as early as in 1983 in connection with the breakthrough of cod juvenile production in mesocosmos system. Through individual tagging and genotyping based on blood and white muscle tissue biopsy, growth performance of the genotype classes for 6 polymorphic proteins were investigated. The same approach was used in two later experiments, carried out in the 1990ies, including one growth / nutritional investigation and a study focused on growth comparison between two different cod stocks (Arctic cod and coastal cod). Overall, genotypic growth performance was investigated in three different experiments and environmental farming conditions based on tagging and genetic screening of several thousand cod specimens. The results are discussed in relation to the potential use in future cod farming industry.

Oral 7

GENETIC VARIATION FOR GROWTH AND SEXUAL MATURITY IN ATLANTIC COD (*GADUS MORHUA*)

Kari Kolstad¹, Bjarne Gjerde¹ and Terje Refstie²

¹ AKVAFORSK (Institute of Aquaculture Research), P.O.Box 5010, N-1432 Ås, Norway;

² AKVAFORSK Genetics Centre, N-6600 Sunndalsøra, Norway

E-mail address: bjarne.gjerde@akvaforsk.nlh.no

Body weights were recorded at tagging (~200 days post fertilization) of in total 6112 Atlantic cod (*Gadus morhua*) offspring of parents caught in two regions off Norway, i.e. 3988 offspring of 20 dams and 28 sires (29 full-sib families) from Region 1 (most likely Norwegian coastal cod) and 2124 offspring of 14 dams and 22 sires (22 full-sib families) from Region 2 (most likely NE Arctic cod). The full-sib families were reared in separate tanks of same type and size from fertilization until tagging size (~25 g). The Region 1 and Region 2 cod was not significantly different in body weight (-4.2 ± 23.5 g) or survival in a 70 days period prior to tagging (-0.1 ± 5.9 % units). The within and across population heritability for body weight estimates were 0.29 ± 0.27 and 0.52 ± 0.26 . These results suggest good prospects for genetic improvement of growth rate in Atlantic cod through selective breeding. However, it is important that these results be verified for body weights recorded at a larger body size and supplemented with similar studies on other traits of economic importance in cod farming. Therefore, after tagging the fish from all families were pooled and are now reared in a floating net cage at four farms along the coast of Norway. Results presented will be based on records obtained at two years of age and will include differences between the Region 1 and Region 2 cod for body weight and sexual maturity, heritability estimates and genetic correlations between the traits and the magnitude of the genotype by farm environment interaction for each trait.

Oral 8

PARENTAL ASSIGNMENT OF ATLANTIC COD (*GADUS MORHUA*)-A CASE STUDY REPORT-

Madjid Delghandi, Mette S. Wesmajervi and Atle Mortensen

Fiskeriforskning Norwegian Institute of Fisheries and Aquaculture Research, 9291 Tromsø, Norway

E-mail address: madjid.delghandi@fiskeriforskning.no

Fiskeriforskning has laid the research foundation for cod breeding in such a way that it will be a commercial farmed species. The basis for a genetic improvement programme in Atlantic cod has been formed and a combined family- and individual selection strategy is chosen. The broodstock are routinely genotyped to characterise the fish as coastal or north-east Arctic cod based on variation at the pantophysin (*Pan1*) locus. For the spawning season 2002-2003, full-sib families were produced primarily by pair-wise spawning. In addition, some egg groups were collected in common broodstock tanks. In order to genotype offspring and parents an assay system for simultaneous analysis of five microsatellite markers has been employed. The assay system is based on fully automated liquid handling instrument, enabling the laborious and time-consuming work done by a robot. Using this assay system it is possible to identify the parents from an individual fish with high efficiency (99.97%). We report here data from parental assignment of more than 2800 offspring from 177 potential parents using the assay system. The data show that the assay system could be used in breeding programs as a tool to study the differences between families or individuals of Atlantic cod. Further, we present calculation of expenses for carrying out parental assignments analysis in our laboratory. Addressing this issue is important, as critical questions concerning the use of genotyping in breeding programs has been arisen.

Oral 9

COD FARMING - AN OPPORTUNITY TO DO IT RIGHT

Esmark, Maren Aschehoug
Marine Conservation Officer, WWF-Norway
E-mail address: mesmark@wwf.no

WWF has witnessed the sad closing of the cod fishery in Canada and the dramatic decline of the cod stocks in the North Sea. Unfortunately, cod farming is not the answer to declining fish stocks. The only solution to overfishing is better fisheries management, meaning reduction in fleet size, ending harmful subsidies and an ecosystem rather than single stock approach to management. From the salmon farming adventure, we know that fish escape, that escaped fish survive and can breed in the wild. We've learned about how diseases and parasites threatens both farmed and wild fish, and how good siting is crucial for limiting the impact on the wider environment. However, today, the single largest challenge for the industry is feed, with a conversion ratio from wild fish to farmed fish sometimes as low as 4:1. The FAO code of conduct for sustainable fisheries urges states to show a precautionary approach when promoting aquaculture, based on the best available scientific information. Cod stocks in many places are severely depleted, and any negative impact from future cod farming can potentially cause severe trouble for already vulnerable stocks, calling for states to use the precautionary approach from day one in developing cod farming. This should be possible using all the experience existing from salmon farming. There are already over 600 licences for cod farming given out in Norway, and WWF cannot find that sufficient environmental regulations are in place. In the question about siting, WWF asks for criteria's defining vulnerable areas and outlining no-go zones for fish farming. WWF urge states farming carnivorous fish such as salmon and cod to address the on-going overfishing of blue whiting, and to promote the use of alternative feed resources, including the use of fish offal, in fish feed.

Oral 10

CONCEPTUAL FRAMEWORK FOR MANAGING THE ENVIRONMENTAL IMPACT OF COD FARMING

Pia Kupka Hansen
Institute of Marine Research, PO B0x 1870, 5817 Bergen, Norway
E-mail address: pia.hansen@imr.no

Cod farming may cause many of the same environmental effects, which has been encountered in salmon farming such as genetic interaction with wild species, disease problems, and impact of medicine, chemicals, organic waste and nutrients. Some of the problems, which have been limited in salmon farming, will be likely to reappear with intensified cod farming. Examples are the lack of vaccines for cod diseases, which may lead to extensive use of antibacterial agents, and the higher feed factor in cod farming which may increase the impact of organic waste and nutrients. Management systems developed for salmon farming to monitor and decrease the impact of waste, excretions and chemicals should be applicable to cod farming and may limit some of the potential effects.

Oral 11

EXPERIMENTAL CHALLENGE OF ATLANTIC COD WITH NODAVIRUS AND INFECTIOUS PANCREATIC NECROSIS VIRUS (IPNV)

Ingvill Jensen, Saskia Mennen, Ann-Inger Sommer
Fiskeriforskning Norwegian Institute of Fisheries and Aquaculture Research
9291 Tromsø, Norway
E-mail address: ingvill.jensen@fiskeriforskning.no

Farming of Atlantic cod is still in its infancy and faces many challenges, including disease problems. Infectious pancreatic necrosis (IPN) and viral nervous necrosis (VNN) are well known problems in aquaculture world-wide and may pose a risk also to Atlantic cod. Aquatic birnaviruses, the etiological agents for IPN, and nodavirus, the etiological agent for VNN, both have broad host ranges and infects several marine fish species. The susceptibility and outcome of these viral infections may vary between different species and sizes of fish. Outbreaks of VNN have been reported in cod fry in the UK and Canada, and IPN has been reported in cod fry in Denmark and the Faeroes. However, very limited information is available regarding the susceptibility of Atlantic cod to viral infections and disease. By experimental challenge we have studied the susceptibility of Atlantic cod to infection with nodavirus and IPNV. Nodavirus isolated from Atlantic halibut suffering from VNN caused significant mortality in Atlantic cod fry (0.5 and 5g) after bath challenge. Nervous symptoms giving erratic swimming behaviour, and fish floating with the belly up due to inflation of the swim bladder was observed and are common clinical signs of VNN observed in several fish species. Darker pigmentation and reduced appetite were also seen, and cumulative mortality reached 34% and 56% over an experimental period of 10 weeks. The susceptibility to IPN was studied in different sizes of cod challenged with different isolates of IPNV. No significant mortality or clinical signs were observed in cod of 0.5g, 0.7g, 13g after challenge, however, IPNV was reisolated from the challenged fish demonstrating the establishment of a covert IPNV infection in cod.

Oral 12

THE RESPONSE OF THE IMMUNOME OF HADDOCK (*MELANOGRAMMUS AEGLEFINUS*) TO VACCINATION

Laura L. Brown¹, Andrew Dacanay¹, B. Erin Bentley¹, Darren Sarty^{1,2}, Stewart C. Johnson¹
¹ National Research Council of Canada – Institute for Marine Biosciences, Halifax, NS, B3H 3Z1
² Department of Biology, Dalhousie University, Halifax, NS
E-mail address: Stewart.Johnson@nrc-cnrc.gc.ca

Two gadid species; Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) are poised to become commercially important species in both European and North America aquaculture. Development of fish-health management strategies will be a crucial step in realizing this potential. The gadids pose an immunological paradox as they have high circulating levels of immunoglobulin (Ig) yet apparently do not produce specific Ig upon vaccination, in contradiction to one of the basic tenets of immunobiology. We investigated this apparent immunodeficiency in haddock by studying Ig gene rearrangements in vaccinated and unvaccinated animals at the genetic, protein and functional levels. When assayed by ELISA neither vaccinated or unvaccinated haddock produced specific Ig to a range of synthetic and bacterin antigens. Analysis of the Ig heavy chain (IgH) by 2-Dimensional electrophoresis confirmed this revealing that no additional Ig specificities were produced. When we analysed the IgH genes we saw the use of a highly diverse range of Ig genes in all groups, vaccinated or unvaccinated. There were no apparent differences in Ig usage between vaccinated and unvaccinated groups. Given that the Ig gene diversity precludes a limited germline immunoglobulin gene repertoire or an inability to rearrange them, we suggest that the paucity of haddock, and indeed cod, immunoglobulin production upon vaccination is due to an inability to access the B-cell repertoire rather than a poor B-cell repertoire itself. These data do not suggest that immunoprophylaxis in gadids is futile but they do show that, as specific Ig is not produced upon vaccination, Ig should not be used to determine the efficacy of vaccination nor should it be used as an indicator of prior disease exposure.

Oral 13

BACTERIA ASSOCIATED WITH EARLY LIFE STAGES OF COD: "NORMAL FLORA" AND PATHOGENS

Øivind Bergh¹, Kjetil Korsnes^{1,2}, Laila Brunvold^{1,3}, Ruth-Anne Sandaa^{1, 3}, and Ole. B. Samuelsen¹,
1. Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway
2. Regional University of Bodø, N-8049 Bodø, Norway
3. Department of Biology, P.O. Box 7800, University of Bergen, N-5020 Bergen, Norway
E-mail address: ovind.bergh@imr.no

A series of experiments have been carried out with the aim of characterising bacterial populations associated with early life stages of cod. Whereas methodology earlier was based on isolation and characterisation of representative bacterial strains from eggs and larvae, new methods have now emerged, allowing for genetic fingerprints of whole bacterial communities, circumventing cultivation of bacteria. Results demonstrate that there is a bacterial flora of cod larvae, which is dependent of hatchery protocols, feed, and probably larval health. Challenge models with yolk sac larvae and fry have been developed in order to study pathogenicity of different bacteria towards different life stages of cod, and pathology associated with infections. In particular, challenge with a particular isolate of *Vibrio anguillarum* serotype O2 has caused mortality. A standard challenge model has been developed, which has been utilised in studies of antibacterial treatments, vaccines and vaccination protocols.

Oral 14

VACCINATION STRATEGIES FOR FARMED ATLANTIC COD, *GADUS MORHUA*

Vera Lund¹, Helene Mikkelsen¹, Susanna Børdal², Kjersti Gravningen³ and Merete B. Schrøder²
1 Norwegian Institute of Fisheries and Aquaculture Research
2 Norwegian College of Fishery Science
3 Alpharma AS, Norway
E-mail address: vera.lund@fiskeriforskning.no

Fiskeriforskning and Norwegian college of Fishery Science have for the past few years been working on vaccine development and strategies for farmed Atlantic cod. Until now vibriosis caused by *Vibrio anguillarum*, has been the main bacterial challenge. However, during the last year atypical strains of *Aeromonas salmonicida* causing atypical furunculosis have frequently been isolated from farmed cod, indicating that the disease may become a problem in near future. Vibriosis vaccines that can protect the codlings as early as possible are required. When using an experimental vaccine from Alpharma, we found that they had to reach a weight of approximately 2 g, before dip-vaccination resulted in an acceptable protection. In addition, codlings dip- vaccinated at 5 g was shown to be well protected when challenged 6 months later. However, to insure long term-protection the cod are revaccinated by injection before they are transferred to net-pens in the sea. Even though it is not yet known if vaccines against atypical furunculosis are needed, we believe that future vaccination strategies for cod will include multivalent injection-vaccines, as used for Atlantic salmon. Thus, we have investigated efficacy and specificity of vibriosis- and furunculosis injections-vaccines. Our results show that the vaccines elicit very good protection when challenged 12 weeks post vaccination. The use of oil-adjuvant resulted in side-effects like adhesions between internal organs in the abdominal cavity, but appeared to have no impact on the growth rate in cod. Furthermore, oil-adjuvant appeared not necessary for obtaining short-term protection. Although strong antibody responses in cod have not been reported until now, we found that the atypical furunculosis vaccines induced antibody responses towards the lipopolysaccharide components of *A. salmonicida*.

Oral 15

MOLECULAR DETECTION AND CHARACTERIZATION OF NODAVIRUS IN SEVERAL MARINE FISH SPECIES FROM THE NORTH WESTERN ATLANTIC

Nellie Gagné¹, Stewart C. Johnson², Marcia Cook-Versloot³, Anne Margaret MacKinnon¹ and Gilles Olivier¹

¹ Fisheries and Oceans Canada, Moncton, NB, Canada

² National Research Council, Halifax, NS, Canada

³ Atlantic Veterinary College, Charlottetown, PEI, Canada

⁴ Research and Productivity Council, Fredericton, NB, Canada

E-mail address: stewart.johnson@nrc-cnrc.gc.ca

Nodaviruses are responsible for causing disease in hatchery-reared larvae and juveniles of a wide variety of fishes throughout the world. This disease has seriously limited the culture of marine fishes over the last decade. In the Atlantic provinces of Canada, disease caused by a nodavirus was first reported in juvenile Atlantic cod being reared in Nova Scotia in 1999. More recently, disease outbreaks caused by nodavirus have been identified in both hatchery-reared Atlantic cod and haddock in Newfoundland, New Brunswick and along the east coast of the United States. The presence of nodavirus in both wild Atlantic cod adults and winter flounder has also been reported. Nodaviruses were isolated from cultured Atlantic cod and haddock as well as wild winter flounder from a variety of geographical localities, and their virus coat (capsid) proteins were partially sequenced. These data showed that all of these nodavirus isolates were closely related to one another but that they were distinct from the European isolates sequenced so far. Regardless of host species, isolates from geographical localities in proximity to one another were more similar than those from distant localities. At the protein level, differences in coat protein sequences were seen only for strains isolated from Atlantic cod in Newfoundland. Our results suggest that NNV may have been present in Atlantic Canada and east coast of USA for some time and has evolved to form a monophyletic group, distinct from other isolates found in cold water species. Non-lethal methods for detection of nodaviruses are necessary to develop management strategies for this disease and would be an asset to diagnosticians and producers. To this end we have developed an RT-PCR assay for the detection of North Atlantic nodaviruses in ovarian fluids, eggs, blood and other tissues. This assay has been used successfully for nodavirus screening.

Oral 16

PHARMACOKINETICS AND EFFICACY OF ANTIBACTERIALS IN COD (*GADUS MORHUA*). AN OVERVIEW

Ole Bent Samuelsen

Institute of Marine Research, Bergen, Norway.

E-mail address: ole.samuelsen@farm.uib.no

The Norwegian aquaculture industry, being almost entirely based on the Atlantic salmon, (*Salmo salar*), and rainbow trout, (*Oncorhynchus mykiss*) has shown interest in domesticating other species for aquaculture purposes. In that respect the cod, (*Gadus morhua*), is regarded as an interesting candidate. Recently, large-scale production of cod-fry has been established and the output of fish for consumption is expected to increase in the years to come. However, bacterial infections especially due to *Vibrio anguillarum* serotype 02 cause severe losses in the production of cod fry and outbreaks usually occur prior to or in connection with vaccination. When outbreak occur, antimicrobial therapy is essential to treat the infection. In order to establish correct dosage regimes and thereby promote optimal use of a drug, data derived from pharmacokinetic investigations and the pathogens susceptibility to the drug in use are essential. However, as the pharmacokinetic properties of antibacterial agents vary significantly between species, the disposition of a drug should be investigated in that particular species in which it is intended to be used.

This lecture will give an overview of the pharmacokinetic properties of the most used antibacterial agents used to treat bacterial infections in cod. Furthermore, data available on the efficacy of drugs will be presented.

Oral 17

IMPROVEMENT OF LIVE FOOD NUTRITIONAL QUALITY

Yoav Barr¹, Synnøve Helland¹

¹ Institute of Aquaculture Research, AKVAFORSK, 6600 Sunndalsøra, Norway

E-mail address: yoav.barr@akvaforsk.nlh.no

Cod fingerlings can be produced using the currently available enriched rotifers and Artemia. However, experimental and commercial growth results show that the use of natural zooplankton gives faster growth rates, thus showing inferior nutritional quality in rotifers and Artemia for cod larvae. Intensively produced cod fingerlings show deformations, high stress susceptibility and low survival; problems that may also be ascribed to malnutrition. Furthermore, malpigmentation and malformation is common in intensively produced halibut larvae. It is therefore likely that a general problem exists in delivering live food with the optimal nutritional quality to cold-water fish larvae. It is believed that part of the advantage of copepods over enriched rotifers and Artemia is the higher content of free amino acids (FAA) and higher polar lipids (PL) content. The aim of the present study is to increase the amount of FAA and PL in live food using liposome that have PL membrane entrapping a FAA solution of high concentration. We are using an enrichment technique that we have developed named "Boosting Enrichment" that uses high doses of enrichment diet and short enrichment incubation, thus allowing the live feed to ingest relatively large amount of diet in a short time and then transfer them to low temperature waters in larval tanks or cold store tanks. This method reduces the absorption and metabolism of diets. A previous disadvantage of liposome as part of diets was the rather laborious production methods when big amounts were needed. However, we have now developed a new version of liposome mass-production method, which is easier, simpler and more efficient than the common methods. Results of liposome chemical composition and the improvement of live feed nutritional quality will be shown.

Oral 18

HYDROLYSED PROTEIN SEEMS TO BE ADVANTAGEOUS FOR COD (*GADUS MORHUA* L.) LARVAE

Audil Kvåle¹, Anders Mangor-Jensen² & Kristin Hamre¹

¹ National Institute for Nutrition and Seafood Research, Bergen, Norway

² Institute of Marine Research, Storebø, Norway

E-mail address: audil.kvaale@nifes.no

The mode of protein digestion is changing during the larval period of marine fish larvae, but the timing of gastrointestinal maturation differs between species. The stomach, where protein digestion starts, is sometimes not developed until metamorphosis. The activity of the dominating pancreatic and intestinal enzymes in juveniles and adult seem to be low by start-feeding, but increase to the juvenile level during the larval period. Simultaneously, protein is a very important dietary ingredient due to high needs both for fast growth and for energy supply. Partly digested protein is therefore thought as beneficial for marine fish larvae. In an experiment cod larvae were fed different amount of pepsin hydrolysed protein (0, 10, 20, 30 and 40% of dietary protein) in triplicate tanks from 33 to 74 days post first-feeding. Growth and survival were registered and activities of some intestinal enzymes were measured to evaluate optimal level of dietary hydrolysed protein. High level of hydrolysed protein (40% vs 0 and 10%) seemed to support survival at weaning as mortality, which was highest at the start of the experiment, were lowest in the tanks fed high level of hydrolysed protein. The enzymatic analysis performed at the end of the experiment, indicated a shift in optimal level of hydrolysed protein towards a medium level at this later developmental stage. To support the result of this experiment a follow-up experiment is ongoing from where results will be presented at the conference.

BIOCHEMICAL COMPOSITION OF COPEPODS FOR EVALUATION OF FEED QUALITY IN JUVENILE PRODUCTION OF MARINE FISH

Terje van der Meeren¹, Rolf Erik Olsen², Hans Jørgen Fyhn³, and Kristin Hamre⁴

¹ Institute of Marine Research, Austevoll, N-5392 Storebø, Norway;

² Institute of Marine Research, Matre, N-5984 Matredal, Norway;

³ University of Bergen, Department of Biology, P.Box 7800, N-5020 Bergen, Norway;

⁴ National Institute of Nutrition and Seafood Research (NIFES), P.Box 176 Sentrum

E-mail address: Terje.van.der.Meeren@imr.no

Biochemical components of copepods from a seawater lagoon were analysed from April to December over two years (2000 and 2001). The samples were taken every fifth day (2000) or weekly (2001), and 56 copepod samples altogether were analysed. Additional samples of rotifers and *Artemia* were included for comparison. Analysed components on each sample were lipid classes, fatty acids of total lipid, free amino acids, total protein, protein-bound amino acids, pigments (astaxanthin and β -carotene), and vitamins (A, B1, B2, C, D3 and E). Copepod size, dry matter content, and fraction of ash were also determined. The data are unique because the samples are very clean with respect to content of copepods (on average 97-98% based on numbers), and it is the first time so many biochemical parameters have been extracted from a single sample over such long period of time. The data are meant to form the base for improved enrichment emulsions and formulated feeds for early use during larval and juvenile stages in marine fish culture. Numbers in this abstract are given as averages for each of the two years of sampling. The results show that copepods are surprisingly stable between species, seasons and years with respect to several of the nutritional components. Copepods may be characterised by moderate levels of lipids (11% of dry weight), dominated by polar lipids (57-58% of total lipid). Three fatty acids are most abundant in total lipid, 16:0 (15%), EPA (16-17%), and DHA (33-34%). The fraction of ARA is very low (0.8-0.9%), which gives an EPA/ARA ratio of about 24. Based on concentration, the fraction of free amino acids (FAA) was 4.7-5.8% of copepod dry weight, and dominated by glycine, arginine and taurine. A correlation between FAA and salinity was found. Essential FAA was 19-24% of total FAA. Protein determined from protein-bound amino acids (PAA) was 41-44% of copepod dry weight. The fraction of essential amino acids in PAA was 40-41% of amino acid concentration. Glycine, glutamine/glutamic acid, alanine, asparagine/aspartic acid, and leucine were the most abundant PAA. Copepods were very abundant in astaxanthin (627-748 μ g/g dry weight), while β -carotene was not found. High concentrations of vitamin C (477-553 μ g/g dry weight) and vitamin E (112-114 μ g/g dry weight) were found, while vitamin A and D3 occurred in trace amounts or were not detected. Compared to the rotifers and *Artemia*, it may be concluded that nutrition in larviculture of cod is not optimal. However, whether this affects larval development, growth and survival is still an open question.

ACCEPTANCE OF A FORMULATED MOIST DIET BASED ON COPEPODS IN EARLY WEANING OF ATLANTIC COD (*GADUS MORHUA*) LARVAE - A PILOT STUDY

P.-A. Wold¹, E. Kjørsvik¹, K. Hoehne-Reitan¹, G. Øie² and K.I. Draget³

¹ Dept. of Biology, Norwegian University of Science and Technology (NTNU), 7491 Trondheim, Norway.

² SINTEF Fisheries and Aquaculture, Department of Bioresources, 7465 Trondheim, Norway.

³ Dept. of Biotech., Norwegian University of Science and Technology (NTNU), 7491 Trondheim, Norway.

E-mail address: Per-Arild.Wold@bio.ntnu.no

Wild cod larvae feed on copepod nauplii, which may contain optimal nutritional composition for growth and survival. Our university has implemented a major strategic research programme to examine the feasibility of using organisms low in the food web as biological raw materials, and we aim to develop new concepts of formulated larval diets based on zooplankton. The aim of this pilot study was to evaluate the acceptance of a gel-based diet made from copepods (*Calanus* sp.) offered to cod larvae. Two feeding experiments were carried out. In the first, cod larvae were fed enriched rotifers and microalgae from 3 dph. Co-feeding with the copepod based diet occurred between 20 and 27 dph, and daily rotifer rations was gradually decreased to 1/3. The control group was offered only rotifers and microalgae. In the second experiment, cod larvae were fed enriched rotifers and microalgae from 3 dph, and enriched *Artemia* nauplii from 18 dph. Co-feeding with *Artemia* and the copepod based diet was carried out between 31 and 49 dph, and daily *Artemia* rations was gradually decreased to 1/3. In the control group, a commercial larval diet was offered in addition to the same live feed rations. The copepod based diet was mixed with water before being supplied continuously to the larval tanks using a pump system. Feeding behaviour was observed when the formulated diets were added to the tanks, and growth rates were similar to the control groups. Larval ingestion of the copepod based feed was confirmed by histological analysis of the larval gut from the first experiment, and by direct observation in the second experiment. Further results on larval performance and histological analysis will be discussed. The results are viewed as promising, and further research on larval nutrition and feeding based on the development of gel-based larval feed types continues.

PRE-HYDROLYSIS IMPROVED THE UTILISATION EFFICIENCY OF A MODEL PROTEIN TUBE FED TO STOMACH-LESS FISH LARVAE

Sigurd Tonheim¹, Marit Espe¹ and Ivar Rønnestad²

¹ National Institute of Nutrition and Seafood Research (NIFES)

² Institute of Biology, University of Bergen

E-mail address: sigurd.tonheim@nifes.no

The digestive capacity of marine fish larvae is debated due to their absence of stomach. Substituting feed protein with hydrolysed protein may improve protein availability. However, concomitant increase in absorptive rates and elevated levels of free amino acids (FAA) in the larval free pool is expected, and increased amino acid (AA) oxidation and reduced protein retention can be a consequence. Thus, to study the effect of increased absorptive rates of dietary proteins in stomach-less fish larvae, radioactive labelled intact protein (IP) and hydrolysed protein (HP) were tube fed to Atlantic halibut larvae and absorption, assimilation and oxidation were compared. The absorption efficiency of IP and HP was similar at small administered amounts (3.5 micrograms). However, the absorption efficiency of IP decreased rapidly as the administered amounts increased, and was significantly ($P < 0.05$) different from HP at doses above 12 micrograms. In contrast, the absorption efficiency of HP was constant at 63% independent of administered amounts (3.5 - 35 micrograms). The rates of absorption in larvae increased 2.2 and 3 times when the protein was hydrolysed to different extents, and resulted in significant ($P < 0.05$) different accumulation of radioactivity in the free AA-pool of larvae administered the respective preparations. AA oxidation was positively correlated to absorption. However, increased rates of absorption did not increase the AA oxidation relative to AA assimilation, as 42% and 49% of the absorbed radioactivity were in CO₂ and body proteins, respectively, independent of degree of hydrolysis and administered amounts. Despite poor utilisation of IP compared to HP in average, high utilisation efficiency of IP was observed in some larvae, indicating that proteolysis can be effective in stomach-less larvae. Data suggested defecation being a critical factor in larva protein utilisation efficiency, as early defecation was observed to occur simultaneously with absorption in larvae administered IP.

Oral 22

AN EVALUATION OF INVE POST-WEANING AND NURSERY DIETS FOR THE COMMERCIAL CULTURE OF COD.

Nick King, Eamonn O'Brien, Sam Ceulemans, Philippe D'Hert, Ed Manchester
INVE Aquaculture Nutrition
E-mail address: nking@inve-us.com

Once weaned onto inert diets, cod have enormous potential for growth and food conversion. A series of feed trials were conducted during 2003 to evaluate INVE post weaning and nursery diets for cod. In three separate trials encompassing fish size from 0.5-20 grams, EPAC CW and IDL CW was evaluated against a reference regime at a commercial cod hatchery. Data will be presented on SGR, FCR, and liver weight ratio. Additionally, performance data from salinity shock stress tests will be used to explain differences in fish condition as a result of varying feed treatments.

Oral 23

WEANING OF ATLANTIC COD (*GADUS MORHUA*) WITH MICROPARTICULATE DIETS MADE OF ALTERNATIVE PROTEIN SOURCES.

Opstad, I.1, Saomi, J.2, and Olsen, R.E 2.
1 Institute of Marine Research, Austevoll, 5392 Storebø
2 Institute of Marine Research, Matre, 5984 Matredal
E-mail address: ingegjerd.opstad@imr.no

A study was conducted to determine the effect of partial or complete substitution of fishmeal with alternative protein sources on growth, survival, deformities and liver index of *Gadus morhua*. Cod larvae were started on rotifers and weaned directly to formulate feed at a mean wet weight of 0,028 g. 50 l tanks with 100 fish in each tank were used. The temperature was kept at 12 °C and the experiment lasted for 30 days. We tested six different diets with three replicates in each group. The mean weight at the end of the experiment differed from 2,52 g (highest) to 0,92 g (lowest). The survival differed from 87 % (highest) to 70 % (lowest). The deformities percentage differed from 16 % (highest) and 0,3 % (lowest). The liver index varied between 11,7 % (highest) and 9,6 % (lowest).

Oral 24

GROWTH, FEED EFFICIENCY AND DIGESTIBILITY IN ATLANTIC COD (*GADUS MORHUA*) FED TWO DIFFERENT FISH MEAL QUALITIES AT THREE DIETARY LEVELS OF VEGETABLE PROTEIN

Sissel Albrektsen¹, Britt Hope¹ and Anders Aksnes¹
1 Norwegian Institute of Fisheries and Aquaculture Research
N-5141 Fyllingsdalen, Bergen, Norway
E-mail address: sissel.albrektsen@fiskeriforskning.no

160 g cod was fed two different fish meal qualities (LT, NSM) at three dietary inclusion levels of vegetable protein. The dietary fish meal (FM) was replaced with a mixture of corn gluten meal and full-fat soybean meal at a fixed ratio of 2:1, providing approximately 10, 30 and 50 % of the dietary protein. The experimental diets were balanced with respect to protein (50%), lipid (18%), gross energy (21.5MJkg⁻¹), Lys (7.5 g/100gprot) and digestible P (0.65%). In the initial 10 week feeding period fish fed low quality FM showed significantly reduced growth and feed conversion as compared to fish fed high quality FM ($p < 0.05$). In the following 10 week feeding period, dietary differences equalized with respect to growth, resulting in a daily specific growth rate of approximately 1 % for all dietary groups ($p = 0.15$). Despite small effects on total growth, reduced protein digestibility and reduced whole body retention of protein and minerals, accompanied by increased fat content, was found in cod fed low quality fish meal. Deposition of excess fat was encountered in the enlarged liver, concomitant with reduced slaughter weight of these fish. By replacing high quality FM by graded inclusion levels of vegetable protein, the feed conversion rate was slightly impaired, but to a smaller extent than by feeding low quality fish meal. Protein digestibility and protein retention was unaffected by exchanging high quality FM with 30% and 50% vegetable protein, and no accumulation of lipid in the liver occurred. Liver size and the hepatosomatic index decreased at 50 % vegetable protein for both fish meal qualities, concomitant with reduced lipid digestibility. In conclusion, there seem to be a potential for application of cheap vegetable protein in feed for cod, on the assumption that high quality fish meal is applied.

Oral 25

GROWTH AND FEED INTAKE IN JUVENILE COD (*GADUS MORHUA* L.) FED CONTINUOUSLY OR DURING LIGHT OR DARK HOURS

Kåre Aas¹, Sten Ivar Siikavuopio¹
Norwegian Institute of Fisheries and Aquaculture Research
Box 6122, NO-9291 Tromsø
E-mail address: kaare.aas@fiskeriforskning.no

This project aimed to investigate the effect of different feeding-regimes on growth and feed intake on juvenile cod. Three experimental groups (duplicated) were held under LD12:12 photoperiod and constant water-temperature (12°C) for six months. Each day all groups were fed in excess using three different regimes; fed continuously (control group), fed during light hours (L12), or fed during dark hours (D12), respectively. No significant differences in body weights were observed among the groups (approx 5 g) at the start of the experiment. At the termination of the trial average body weight in the D12 group (95 g) was significantly higher compared to L12 fish (88 g), whereas the control group took an intermediate position (91 g). The D12 group appeared to have higher feed conversion efficiency compared to the other groups. No bite-marks were observed in the fish, indicating a low level of negative social interactions within the experimental groups. After six months, 20 % of the males were found to be mature, independent of group.

POSITIVE CORRELATIONS BETWEEN EGG DRY WEIGHT, LARVAL SIZE AND MUSCLE GROWTH IN ATLANTIC COD

Iver Tanem, Elin Kjørsvik and Trina F. Galloway
Department of Biology, Norwegian University of Science and Technology (NTNU), 7491 Trondheim, Norway.
E-mail address: ivert@stud.ntnu.no

The aim of this study was to examine correlations between egg quality (fertilisation rate, rate of normal blastomers and egg size) and egg survival (hatching rate), larval quality (larval size and survival in a functionality test) at first feeding and muscle growth (number and size of muscle fibres) in an Atlantic cod (*Gadus morhua* L.) breeding program. Thirty egg batches of different Norwegian cod stocks were incubated at Akvaforsk (Averøy, Norway) during March 2002. The eggs were collected from natural spawnings between one female and one male. Each female was paired with two males in subsequent spawnings, resulting in 2 half sibling groups per female. The egg groups were incubated until day 5 post hatching. There were no correlations between fertilisation rate or rate of normal blastomers and egg survival, larval size and muscle mass size. There were no correlations between egg diameter and hatching rate, number of muscle fibres and muscle mass size but there was an increase in standard length and muscle fibre size with increasing egg diameter. Hatching rate was not correlated with egg dry weight, but there was an increase in standard length, larval dry weight, number and size of red and white muscle fibres and total muscle mass size with increasing egg dry weight. There were relatively small variations between half sibling groups in time to LC50 in the functionality test. From these results we can conclude that egg dry weight is a better predictive measure of yolk sac larval morphology than other egg quality criteria (fertilisation rate, rate of normal blastomers and egg diameter). Which role the egg quality criteria have past the yolk sac stage was not evaluated in this work, but they may influence the success of first feeding, weaning or metamorphosis.

BEHAVIOUR OF ATLANTIC COD (*GADUS MORHUA*) LARVAE: AN ATTEMPT TO LINK MATERNAL CONDITION WITH LARVAL QUALITY

Howard I. Browman^{1,2}, Jean-François St-Pierre¹, Anne Berit Skiftesvik², and Roberto G. Racca³
¹ Department of Fisheries and Oceans Canada, Ocean Science Division, Maurice Lamontagne Institute, P.O. Box 1000, 850 Route de la Mer, Mont-Joli, Quebec, Canada, G5H 3Z4;
² Current address: Institute of Marine Research-Austevoll, N-5392 Storebø, Norway,
³ JASCO Research Ltd., Suite 2101-4464 Markham Street, Victoria, B.C., Canada, V8Z 7X8
E-mail address: howard.browman@imr.no

To characterize possible links between the condition of Atlantic cod females and that of their progeny, we tested the hypotheses that female nutritional status, size and/or incubation temperature are related to larval quality (growth rate and behaviour). Fertilized eggs were obtained from discrete spawning couples that had been maintained under controlled feeding and temperature regimes. The treatments applied to cod females were maternal ration x maternal temperature history and, in a second experiment, maternal ration x maternal size. Three of the five or six male-female pairs from each of the four ration-temperature treatment groups, or ration-size treatment groups were targeted as sources of fertilized eggs. Larvae from these groups were subsampled at various intervals and their size and dry mass measured. Specific growth rate (SGR) was calculated from these data. Silhouette video photography (SVP) was used to record the behaviour of cod larvae originating from these females-egg groups. The significant relationships between larval SGR and the swim path variables extracted from our behavioural observations support their use as indicators of larval performance-quality. While the incubation temperature of cod females was not related to our behavioural proxies of larval performance, there was at least an indication of a link with maternal size and ration, although the behavioural responses were inconsistent and, therefore, difficult to interpret. We conclude that, at least under non-extreme conditions (i.e., very low or very high temperatures and/or nutritional condition and/or size), the condition of cod females does not strongly affect the behavioural performance of the larvae that they produce. This conclusion must be qualified by saying that the behaviour of cod larvae from even a single male-female cross and egg batch is highly variable and that this confounds (and possibly masks) differences in the overall performance of larval groups.

OLFACTORY SENSITIVITY OF JUVENILE COD TO AMINO ACIDS

Syed Yahiya Yacoob, Howard I. Browman, Per Anders Jensen
Institute of Marine Research, Austevoll Aquaculture Research Station, N-5392 Storebø, Norway
E-mail address: syed@imr.no

Olfactory sensitivity of 0-group Atlantic cod (*Gadus morhua*) was studied by recording electroencephalograms (EEG) from the olfactory bulb. Juvenile cod has very well developed olfactory rosette (OR), connected to the olfactory bulb (OB) with short olfactory nerve. Application of chemical stimuli to the OR produced large rhythmic oscillatory electrical responses (EEGs) in OB. The magnitudes of electrical responses to 20 amino acids were measured at 10⁻⁴ M and expressed as percentages of one standard amino acid (relative stimulatory effectiveness, RSE). Based on the RSE, leucine, methionine, asparagine, glutamine, alanine and threonine were highly stimulatory; proline, phenylalanine, aspartic acid and tryptophan were the least stimulatory. To determine if the RSEs would alter at lower concentrations, responses to the same amino acids were also measured at 10⁻⁶ M. With only a small number of exceptions, the stimulatory ranking of RSEs at 10⁻⁶ M was the same as that at 10⁻⁴ M. However, the ranks of some amino acids (arginine, histidine, lysine and glutamic acid) were much lower at 10⁻⁶ M than at 10⁻⁴ M. Threshold concentrations necessary to evoke an apparent EEG response were determined by generating concentration–response relations for four amino acids: 10⁻⁸ M for alanine, 10⁻⁷ M for leucine and arginine, and 10⁻⁶ M for glutamic acid. Responses to all four amino acids were positively correlated with stimulus concentration, although the response to leucine saturated at 10⁻³ M. The overall ranking of amino acid RSEs for cod, and the threshold concentrations of the four amino acids tested, are comparable to those reported for other species of fish. However, the response of juvenile cod to leucine was much higher than that exhibited by other species.

DIFFERENCES IN SPATIAL LANDSCAPE IN NURSERY HABITATS AND ASYMMETRIES IN AGGRESSIVE INTERACTIONS IN HATCHERY REARED NORTH SEA COD

Anne Gro Veia Salvanes¹ and Victoria A. Braithwaite²
¹Department of Marine Biology, University of Bergen P.O.Box 7800, N-5020 Bergen, Norway
² Institute of Cell, Animal, and Population Biology, School of Biological Sciences, University of Edinburgh, EH9 3JT, UK.
E-mail address: Anne.Salvanes@ifm.uib.no

Many re-introduction programs used for conservation of populations and species threatened with extinction advocate the use of enriched rearing environments, and training animals to behave appropriately for surviving future hazards. Curiously, most of the current fish restocking programs have paid little attention to lessons previously learned in bird and mammal reintroductions. Most released hatchery fish perish after short periods in the wild. One possible explanation is based purely on selection processes; many hatchery fish normally selected out of the population in the wild thrive in predator free, food rich hatcheries. Alternatively, nursery environments may fail to shape fish behaviour appropriately; hatchery fish experience very impoverished environments compared to wild fish. Here, we untangle experimentally the role of spatial heterogeneity in hatcheries on behavioural development of North Sea cod (*Gadus morhua*). We find asymmetries in aggressive behaviour when fish reared in different hatchery environments later meet. Cod reared in standard hatchery, impoverished environments obtain less access to shelter, are more active, and show weaker antipredator responses than fish reared with access to heterogeneous spatial landscapes. These results suggest that the homogeneous environments of fish farms generate deficits in behavioural traits that could reasonably be expected to be associated with lower survival in the wild.

Oral 30

EFFECTS OF WATER QUALITY AND STOCKING DENSITY ON GROWTH RATE, NUTRITIONAL CONDITION AND MORTALITY OF JUVENILE COD (*GADUS MORHUA* L.)

Björn Björnsson, Sólveig R. Ólafsdóttir
Marine Research Institute, Skúlagata 4, P.O. Box 1390, 121 Reykjavík, Iceland
E-mail address: bjornb@hafro.is

In a five month experiment where groups of juvenile cod were reared in a flow-through system at low density (Group 1) and in a recirculating system at low (Group 2) and high density (Group 3) the recirculated water had negative effect on growth rate, nutritional condition and mortality. Already after the first month the mean weight was significantly larger in Group 1 than in the other two groups. The effects of stocking density on mean weight were not significant until at the end of the experiment when it had reached 9.0 and 48.3 kg/m³ in Groups 2 and 3, respectively. The mean weight was initially 37.3 g and finally 225.2, 181.8 and 167.9 g in Groups 1, 2 and 3, respectively. At the end of the experiment the mean condition factor was 1.074, 0.965 and 0.946, the mean liver index 9.5, 9.0 and 7.6 and the mean mortality 1.0, 5.1 and 2.4% in Groups 1, 2 and 3, respectively. Mean values of temperature (10.5°C), pH (7.3) and oxygen concentration (8-10 mg/L) were similar in all groups. Concentration of total ammonium nitrogen (TAN) was similar in all groups for the first half of the experiment (0.3-0.4), but during the last month it was 0.6, 1.3 and 1.5 mg N/L in Groups 1, 2 and 3, respectively. There was a highly significant negative correlation between relative growth rate and TAN suggesting that ammonia was a limiting factor in the recirculating system. As diurnal changes in TAN were not measured it was not possible to estimate accurately the threshold value of TAN for the growth of juvenile cod but it may have been close to 1 mg N/L.

Oral 31

TEMPERATURE EFFECTS ON THE METABOLIC COST OF GROWTH IN DEVELOPING ATLANTIC COD, *GADUS MORHUA*

McCollum A., Geubtner J., and I. Hunt von Herbing.
University of Maine, School of Marine Sciences
E-mail address: arthur.mccollum@umit.maine.edu

This study investigates the effects of temperature on the metabolic cost of growth in developing Atlantic cod (*Gadus morhua*). Almost all marine fish produce planktonic larvae that are temperature sensitive, have high growth rates (20-50% d⁻¹) and high cumulative mortality rates (>95%). Growth rates can decrease more than 4-fold between larval and juvenile stages and become more temperature tolerant at older stages. In slow growing larvae at low temperature, growth and metabolism are positively related, but in fast growing larvae these rates become uncoupled resulting in "cost-free" growth. In this study, two variables were measured throughout development at 2 different temperatures: 1) specific dynamic action (SDA), an index of the metabolic cost of growth, and 2) total metabolic heat output (Rt) (the total energy available for all activities). All metabolic heat output measurements were made using a Thermometric LKB 2277 microcalorimeter (TAM) and results suggest that larval cod experience SDA after feeding and that growth rates appear to scale more steeply than the cost of growth (SDA) with mass at a given temperature. At high growth rates, growth and metabolism appeared uncoupled. For cod larvae fed to satiation on rotifers, metabolic rates (measured as changes in heat output) increased slightly (0.75 times standard rates) at 13 dph (days post-hatching) (7mm). The magnitude of SDA continued to increase with larval size reaching rates that were 4 to 5 times that of standard rates at 28 dph (11mm). Although we are cautious in relating changes in heat output directly to SDA, these results are unique for fish larvae. This study will provide important new knowledge on the energetics of early fish growth, which is directly applicable to cod aquaculture as it examines the effects of temperature on the physiological mechanisms that underlie the decrease in growth rate as larvae transform into juveniles.

Oral 32

EFFECTS OF TEMPERATURE, BODY SIZE AND FEEDING LEVEL ON THE GROWTH BIOENERGETICS OF YOUNG JUVENILE COD (*GADUS MORHUA*) AND HADDOCK (*MELANOGRAMMUS AEGLEFINUS*)

Myron A. Peck 1, Lawrence J. Buckley 2, David A. Bengtson 3, Axel Temming 1

1 Institute for Hydrobiology and Fisheries Research, University of Hamburg, Olbersweg 24, 22767, Hamburg, Germany

2 URI-NOAA CMER Program, Graduate School of Oceanography, University of Rhode Island, Narragansett, Rhode Island, 02882 USA

3 Department of Fisheries, Animal and Veterinary Science, University of Rhode Island, Kingston, Rhode Island, 02881, USA

E-mail address: myron.peck@uni-hamburg.de

This presentation summarizes the results of experiments conducted to understand the growth bioenergetics of young juvenile cod and haddock. During laboratory experiments, we quantified the effects of temperature, body size, and feeding level on: 1) energy gained in growth, 2) fish growth efficiency, and 3) energy losses due to metabolism. The somatic growth and growth efficiency of both species were measured in a series of 14-day feeding trials conducted at 5, 8, 12, and 15 °C. Routine and feeding energy losses were estimated via flow-through respirometry trials conducted at the same four temperatures. Maintenance rations (food intake at zero growth) from feeding trials compared well with rates of energy loss estimated from respirometry. The growth-feeding relationship of early juvenile cod and haddock is compared to that of larger juvenile and adult gadoids. Respiratory data from this and other studies were compared and combined to generate an equation estimating routine energy loss at different temperatures and body sizes for cod. Respiration data collected in 18 studies were examined. The model that explained the most variance in measured energy loss and exhibited the least trend in the residuals was one that incorporated stage- (weight-) specific changes in the allometric scaling of size (weight) and the exponential scaling of temperature on rates of energy loss. The model should be useful when estimates of energy loss are required for Atlantic cod.

Oral 33

WEIGHT GAIN AND LIPID DEPOSITION IN JUVENILE ATLANTIC COD, *GADUS MORHUA*, DURING COMPENSATORY GROWTH.

Karen Smith and Joseph Brown

Ocean Sciences Centre, Memorial University of Newfoundland and Labrador

E-mail address: karens@mun.ca

Feed-restricted fish gain less body mass and storage reserves than well-fed fish. Reduced rates of gain can generate a compensatory response, characterised by increased appetite and growth rate. The results of previous studies have generated a hypothesis which states that fat reserves regulate the compensatory response. An expansion of this suggests that compensatory growth is related to the severity of the feed restriction, and that the compensatory response will terminate once fat reserves are restored. We tested this hypothesis in an experiment in which juvenile Atlantic cod were subjected to various intervals of no-feeding and re-feeding for 5 months. Fixed no-feed periods of 2, 4 or 8d distinguished the treatment groups. At the end of the experiment, previously feed-restricted fish subjected to 2 and 4d no-feed periods had fully compensated for their lost weight gain compared to continuously fed control fish. Body composition in terms of liver lipid stores will be discussed in relation to the hypothesis.

NITROGEN RETENTION OF FARMED ATLANTIC COD (*GADUS MORHUA L.*) FED ON A COMMERCIAL DIET.

Marine Herlin, Trevor Telfer and William Roy,
Institute of Aquaculture, University of Stirling, Scotland
E-mail address: mcgh1@stir.ac.uk

Atlantic cod farming is a newly established industry in Scotland with considerable economic potential reinforced by the significant depletion of most major cod fisheries in Northern Europe. However, there is little published information available on release of wastes to the environment and retention of nutrients with commercial and formulated diets. The following nutritional study provides preliminary data to allow calculation of levels of nitrogen retention in cod tissues, and compares these results with equivalent data for Atlantic salmon. Cod gave apparent digestibility results of 79.8% for a commercial cod feed. This is slightly poorer than Atlantic salmon which has a published digestibility value of 85%. Results also indicated that for the commercial diet, cod effectively retained 27% of the total amount of nitrogen eaten. Studies on newly developed high energy salmon diets give a nitrogen retention of between 35-40%. On the basis of these preliminary results cod has poorer digestibility and nitrogen retention than Atlantic salmon. However, the results for salmon were from studies undertaken with high energy diets which are the product of many years of research. The results for cod, compared with those for salmon, are encouraging that these levels can be achieved at such an early age in the industry. The results also suggest that, based on direct comparison of nitrogen retention by the two fish, cod would discharge approximately 1.2 times as much nitrogen as salmon, at present. This is lower than the comparison factor of 1.5 suggested by the Scottish Executive (SEERAD), and employed by the Scottish Environment Protection Agency (SEPA) for environmental regulation. Further work should be done to refine these results, especially with newly developed commercial cod feeds, as they become available, which may improve digestibility and nutrient retention.

COD PUBERTY – AGE AT FIRST MATURATION IN RELATION TO SEASONAL GROWTH AND ENERGY ACQUISITION DURING THE FIRST YEAR OF LIFE

Birgitta Norberg¹, Ørjan Karlsen¹, Geir Lasse Taranger² and Olav S. Kjesbu²
¹ Institute of Marine Research, Austevoll, N-5392 Storebø, Norway
² Institute of Marine Research, PO Box 1870 Nordnes, N-5817 Bergen, Norway
E-mail address: birgitta.norberg@imr.no

A major bottleneck in farming of Atlantic cod is early sexual maturation, which commonly occurs at two years of age in farmed cod. Recent experiments indicated that growth rate or body size during the first year after hatch may affect the age of puberty. Consequently, the aim of this study was to analyse the seasonal effects of different growth rate on age at puberty. A long-term experiment was performed, where growth rate during the first year was controlled by varying feed ration between October and February. The experimental treatment was terminated in May, thereafter the groups were sorted by size, pooled into three net pens and fed ad lib until February the following year (two years of age). Incidence of maturation at one and two years of age was recorded, and related to growth rate and plasma levels of 11-ketotestosterone (males) and IGF-1 during the first year. First-year ovaries and testes were analysed histologically for intensity of oogonial proliferation, oocyte development, and spermatogenesis. Potential fecundity was determined in prespawning females, by a combination of measurements of ovarian size and mean oocyte size to estimate oocyte numbers. Results indicate that restricted feeding before Christmas the first year reduced incidence of male maturation at one year of age. Further, restricted feeding influenced incidence of maturation in both male and female cod at two years of age. No apparent correlation was found between plasma IGF-1 and 11-KT or maturity status in males during the first year.

Oral 36

PHOTOPERIOD CONTROL OF MATURATION AND GROWTH IN GADOIDS: AN ESSENTIAL TOOL FOR COMMERCIAL CULTURE.

Andrew Davie¹, Herve Migaud¹, Carlos Mazorra², Mark Porter³, Jim Treasurer² and Niall Bromage¹,
1 Institute of Aquaculture, University of Stirling, Stirling UK
2 SAMS Ardtoe, Acharacle. Argyll, UK
3 School of Aquaculture, University of Tasmania, Launceston, Tasmania, Australia
E-mail address: andrew.davie@stir.ac.uk

Maturation during ongrowing is a problem for commercial culture of gadoids. This paper discusses the findings from a series of trials in the UK which have focused on quantifying the impact of maturation during ongrowing and its control through photoperiod manipulation in both Atlantic cod (*Gadus morhua*) and Haddock (*Melanogrammus aeglefinus*). The first project, focusing on cod, examined the importance of applying continuous light (LL) between 6-18 months post-hatch in light-proofed tanks. The impact of photoperiod treatment on maturation, flesh & liver composition and sex related growth performance provide a comprehensive insight into the efficacy of photoperiod regulation in the control of maturation in cod. The second project focused on haddock. In its first phase validating melatonin measurement techniques and demonstrating for the first time the seasonal plasma melatonin rhythms in the species to compare them with those exhibited by other fish of aquaculture interest. The second phase then examined the potential impact of maturation during ongrowing as well as its possible remediation through artificial photoperiod manipulation. Populations of haddock experiencing two different test photoperiods displayed improved growth performance and altered maturation commitment when compared to a population raised on an ambient seasonal photoperiod. The results demonstrate how photoperiod manipulation is an essential tool in gadoid aquaculture to inhibit maturation and hence improve growth potential, product quality and arguably animal welfare. This work was supported in various places by NERC studentship NER/S/A/2000/03640, BMFA, University of Stirling, Seafish, SAMS & HIE.

Oral 37

EFFECT OF DIFFERENT PHOTOPERIODS AND LIGHT INTENSITY ON PUBERTY AND MELATONIN PROFILES IN COD

Geir Lasse Taranger¹, Herve Migaud², Olav Sigurd Kjesbu¹, Leiv Aardal¹, Tom Hansen¹
1 Institute of Marine Research, PO Box 1870 Nordnes, 5817 Bergen, Norway.
2 Institute of Aquaculture, University of Stirling, UK
E-mail address: geirt@imr.no

Prevention of early sexual maturation is essential in Atlantic cod farming, as maturity results in loss of growth and flesh quality, and consequently increased production costs. Typically almost 100% of the farmed cod mature at two years of age, when the fish are too small for harvest. Continuous light (LL) treatment in indoor tanks has been found to delay puberty in cod by at least one year. Two trials were conducted at a commercial fish farm in western Norway (60° N) to test the effect of LL superimposed on ambient light (LL-A) on cod in sea cages. These trials indicated that LL-A from midsummer (15 months old cod) or September (18 month old cod) onwards delayed gonadal development compared with controls under natural light. However, the delaying effect of the LL-A treatment were less than of the LL treatment in indoor tanks. A possible explanation for this could be the light intensity of the LL-A treatment was too low compared with the day-time light in the cages. Previous studies indicated that the diel rhythm of melatonin was fully suppressed in cod under LL, but only partially suppressed under LL-A. It was suggested that night-time melatonin levels had to be suppressed below a certain level to get the full delaying effect on puberty. A short-term trial in small indoor seawater tanks tested different ratios in light intensities between day and 'night' on plasma melatonin levels in cod adapted to a LD12:12 photoperiod. Ratios of day-time over night-time intensity of approx. 1000:1, 100:1, 10:1 and 1:1 appeared to be equally effective in suppressing plasma melatonin levels in cod, compared to darkness during night. Consequences of these findings for practical application of LL-A treatment on sea cages will be discussed.

Oral 38

GROWTH RATE VARIATION AND GROWTH PREDICTION IN CULTIVATED ATLANTIC COD

Richard Alderson¹ and Trina F. Galloway²

¹ BioMar Ltd, North Shore Rd, Grangemouth FK3 8UL, Scotland, UK

² BioMar AS, Kjøpmannsgt 50, 7484 Trondheim, Norway

E-mail address: dalderson@biomar.co.uk

As part of the process of developing and testing cod diets, growth rates of more than 6,000 individually tagged cod, of sizes ranging from 80 g to 4 kg have been measured. The growth trials have been conducted over a wide range of environmental conditions, and in one case cover a full production cycle of 2 years. These trials have enabled comparisons to be made between growth of males and females and the data also clearly show the effect on growth rate of sexual maturity. The impact of temperature and season on growth are also demonstrated in the data, and included in this can be seen the adverse effect of very high summer temperatures. This provides useful data on the upper limits for growth in the strain of cod used in the trials. One of the results of this work has been the development of improved growth rate tables for the prediction of growth in the farming process. In addition to improving the planning process within the farming operations, from predicting feed demand to the planning of harvests, these tables are also valuable for the evaluation of potential sites for farming. In addition, the wide variation in growth rate observed, both within and between populations studied, also serves to demonstrate the potential for improvement in cod growth that will arise as the species is selected for the farming process.

Oral 39

GROWTH, SURVIVAL, DIET AND ON-GROWING HUSBANDRY OF HADDOCK *MELANOGRAMMUS AEGLEFINUS* IN TANKS AND SEA CAGES IN SCOTLAND

Jim Treasurer¹ and Harald Sveier²

¹ SAMSArdoe, Ardtoe Marine Laboratory, Acharacle, Argyll PH36 4LD, UK

² Ewos Innovation, 4335 Dirdal, Norway

E-mail address: jim.treasurer@sams.ac.uk

Haddock have been farmed in a demonstration project in Scotland from 2002-2004 supported by SAMSArdoe, Seafish, Ewos Innovation, Mainstream, Macrae, HIE and Aberdeenshire Council. A total of 17,000 juveniles was transferred to onshore tanks for on-growing in 2002 and 15,000 fish were sent to sea cages on two farms in 2003. Growth of haddock in tanks in 2003 was initially good with a mean SGR of 0.64 and FCR of 0.74. However, growth later was poor and suggests a difficulty in haddock utilising lipid in their diet. Hence, growth rates and SGRs compared unfavourably with cod. The mean liver weight as a percentage of body weight increased to over 17% in the second year and lipid in the diet was consequently reduced from 14% to 10%. Fish were transferred to a photoperiod regime with 24 hour continuous lighting from May of the first on-growing year and fish were not mature at age 2, unlike all fish that matured under an ambient light regime. Mortalities during on-growing were mainly due to *Vibrio* infection, enlarged liver, or *Flexibacter* infection. An assessment of the quality of farmed haddock found the taste and texture to be good and this was improved following a short starve period. The unusually large livers and consequent diminished growth rate remains the main obstacle to farming haddock and the true economic cost of farming haddock still has to be determined. Future research will focus on resolving the dietary requirements to avoid enhanced liver weight.

COMPARISON OF PERFORMANCE OF TWO SIZE GROUPS OF FARMED COD JUVENILES FOLLOWING TRANSFER TO SEA

Justin T Watson, Stewart Sales, Grant Cumming, Stuart D Fitzsimmons, Jon Walden, Gregg Arthur, Saro Saravanan, and Lesley A McEvoy
The North Atlantic Fisheries College, Port Arthur, Scalloway, Shetland, UK, ZE1 OUN
E-mail address: jtwatsonrec@hotmail.com

One of the major obstacles currently impeding cod aquaculture is the lack of data regarding the optimum size of juveniles for transfer to sea cage sites. The biological and economically optimum size for sea transfer was investigated. Replicated trials were undertaken using enclosures (1.5 m × 1 m x 1m) stocked with two size grades of cod juveniles previously 'untested' for grow-out at sea in Shetland. The following weight grades were chosen: Group A, 9.34 g mean weight (SD± 2.085) and Group B, 19.4 g mean weight (SD± 4.486). The fish were fed to satiation twice daily. Growth parameters such as length, weight and condition factor were measured at fortnightly intervals for a total of two months duration. Daily mortalities, visible signs of pathology, predation, and overall survival were also recorded. The data showed no significant difference in survival between the groups tested, with overall mortality at 7.3 % (Group A) and 8.4 % (Group B). A significant difference was observed in the overall specific growth rate (SGR) ($P = 0.02$), with Groups A and B exhibiting values of 1.3 and 1.07, respectively. Regression analysis of body weight gain over time between the two groups revealed a significantly higher proportional weight gain in Group A ($P = 0.01$). Cost analysis reveals an initial saving of 8.5 % by selecting Group A juveniles. This saving was reduced to 2.9% when the cost of feeding these fish was taken into account. However, food wastage was higher in this study than would be expected in a commercial operation, suggesting that the saving for the on-grower will be greater than 2.9%. Selecting smaller sized juveniles for transfer may increase the grow-out period. However, this is largely negated by the fact they may be transferred earlier, at a significantly lower price.

CODGEN – MAPPING OF THE GENOME OF ATLANTIC COD AT A MOLECULAR LEVEL

Audun H. Nerland
Institute of Marine Research, Norway
E-mail address: audun.nerland@imr.no

Atlantic cod is one of our most important fish resources, and the species also has the potential for a substantial aquaculture production. However, for both aspects new biological knowledge is essential. For sustainable managements of wild stocks we need to know how climate changes and pollutants influence recruitments and performance of the wild fish in the sea. For the success of cod aquaculture biological bottlenecks like timing of sexual maturation, start feeding, deformities and disease control have to be solved. Genes, and gene regulation, are the basis for most of these biological functions. Functional genome studies of which genes are involved, and how they are controlled and coordinated, will generate information enabling us to understand the underlying mechanisms, which again may make it possible to solve the problems. Mapping of the Atlantic cod genome has been started to provide sequence information essential for functional genome studies. The first part of it will be large scaled sequencing of ESTs (expressed sequence tags). mRNA from various tissues like liver, kidney, pituitary gland, gonads, spleen, intestine, as well as whole larvae at different development stages, has been isolated, converted to cDNA by reverse transcriptase and cloned into a plasmid vector in an orientated manner. Recombinant plasmid DNA is transformed into E.coli and colonies are randomly picked and sequenced using universal primers binding to flanking sequences of the vector. The collection of clones, and the sequence information will be used in microarray studies that will be applied to elucidate which genes are involved in specific biological processes of interest. The sequence information will also make it possible to design primers and probes for Real-time RT-PCR enabling more detailed studies of the regulation of the genes involved in a process.

Oral 42

GROWTH AND SURVIVAL OF ATLANTIC COD LARVAE FROM FOUR LATITUDINALLY SEPARATED POPULATIONS: IMPLICATIONS FOR BROODSTOCK DEVELOPMENT.

Velmurugu Puvanendran, Anne Kellett and Joseph A. Brown
Ocean Sciences Centre, Memorial University, St. John's, Newfoundland, Canada A1C 5S7
E-mail address: Puvy@mun.ca

Latitudinal differences in growth and survival of fish populations have been documented in several recent studies. In general northern population grow better than their southern counterparts. We carried out common garden experiments on larval cod from four regions in the North Atlantic, 3L (Bonavista Bay, NF. 49°N), 3PS (Placentia Bay, NF. 48°N; 54°W), 4T (Northumberland Strait, P.E.I. 46°N; 64°W) and 4X (Scotian Shelf, NS, 44°N) to determine if larvae from these populations would display different growth rates and survival. Experiments were carried out at two temperatures (7 and 11°C) and two prey concentrations (1500 and 4500 prey/L). Larvae were sampled from 1 to 43 days post-hatch for growth and larval survival was recorded at the end of the experiment. Our results showed significant effects of prey density, temperature and population on larval growth with the southern 4X larvae were significantly smaller than 4T and 3PS larvae. Likewise, both prey density and temperature affected survival among these populations, however, prey density had a more significant effect than temperature. Survival of 4T and 3PS larvae was influenced by prey density while survival of 4X larvae was affected by temperature. We discuss our results in the context of selecting appropriate broodstock for cod the aquaculture industry.

Oral 43

ARE DIFFERENCES IN SHORT-TERM AND LONG-TERM GROWTH AND NUTRITIONAL CONDITION ESTIMATES OF LARVAL AND JUVENILE COD RELATED TO MATERNAL EFFECTS?

Catriona Clemmesen¹, Vivian Buehler¹, Gary Carvalho², Richard Case², Lorenz Hauser², William Hutchinson², Olav Sigurd Kjesbu³, Erlend Moksness⁴, Haakon Otteraa³, Helge Paulsen⁵, Anders Thorsen³, Benedikte Willert¹ & Terje Svaasand³
¹ Leibniz-Institute of Marine Sciences at the University of Kiel, Düsternbrooker Weg 20, 24105 Kiel, Germany
² The University of Hull, Molecular Ecology & Fisheries Genetics Group, Dept. of Biological Sciences, Cottingham Road, HU6 7RX Hull, UK
³ Institute of Marine Research, P.O. Box 1870 Nordnes, 5817 Bergen, Norway
⁴ Institute of Marine Research-Flødevigen Research Station, N-4817 His, Norway
⁵ Danish Institute for Fisheries Research, P.O. Box 101, 9850 Hirtshals, Denmark
E-mail address: clemmesen@ifm-geomar.de

The effect of maternal condition and spawning experience was followed in Norwegian Arctic cod from egg stage to 10 week old juveniles. Newly hatched larvae were reared in experimental trials under semi-natural conditions in two large mesocosms (2500m³ and 4400m³) in the years 2000 and 2001. Parental identity of newly-hatched to ten weeks juveniles was determined by DNA microsatellite fingerprinting methods. Larval and juvenile performance was measured based on short-term (RNA/DNA ratio) and long-term growth and nutritional condition estimates (size, weight, liver index, glycolytic enzymes (lactate dehydrogenase, pyruvate kinase)). Variability in these parameters was analysed in relation to maternal spawning experience (recruit vs repeat spawner), egg size, maternal phenotype and food availability. Although the food situation had a significant effect on the performance of the offspring, maternal size and egg size were related to larval/juvenile size and weight throughout the whole rearing period. The importance of the maternal effect on the different growth and condition estimates will be discussed.

Oral 44

SPAWNING BEHAVIOUR AND REPRODUCTIVE SUCCESS IN COD, *GADUS MORHUA* L.

Linda A. Hansen, Børge Damsgård and Madjid Delghandi
Fiskeriforsking, 9291 Tromsø, Norway
E-Mail address: linda.hansen@fiskeriforsking.no

The relationships between spawning behaviour and reproductive success in cod are only partly known. This study was performed to quantify individual reproductive behaviour and describe traits in individuals that might perform satisfactory in breeding and farming. In the experiment, 15 female and 15 male wild caught cod (average weight 6 kg) were kept from February to June 2003 in a 5-m diameter tank under natural temperature and light conditions. All fish were individually marked with external tags and individual behaviours were registered by using a video analysis system (The Observer Video-Pro, Noldus Information Technologies, The Netherlands). Video recordings were done regularly, and recordings were analysed for specific behaviours, initiator, recipient and time of occurrence. Each morning fertilised eggs were collected and the time of spawning estimated from the developmental stage related to water temperature. Collected eggs from all spawnings were genetically tested for paternity by using an assay system containing five microsatellite loci. This system enables the identification of the offspring parents with high efficiency (99,9%). In total 43 egg batches were collected and analysed. Most spawnings were estimated to have occurred in the afternoon and at night. Many individuals were active during courtship and spawning, but from two females no fertilised eggs were found during the whole spawning season. Five females and five males were responsible for a large amount of the sampled fertilised eggs, 77 % and 54 %, respectively. However, the spawning fish were not always the same individuals that were observed courting. Preliminary video analyses indicate that the males initiated courtship, and the behaviours were directed towards both females and males. All females except two fish were courted once or more during the first three weeks of spawning, and the average courting lasted approximately 13 seconds.

Oral 45

PARENTAL EFFECTS ON EARLY LIFE HISTORY TRAITS OF HADDOCK, *MELANOGRAMMUS AEGLEFINUS*

W. Nikolaus Probst 1, Edward A. Trippel 2, Rick M. Rideout 2, and Gerd Kraus 1
1 Institute for Marine Sciences, Dusternbrooker Weg 20, D-24105 Kiel, Germany
2 Fisheries and Oceans Canada, Biological Station, St. Andrews, NB, E5B 2L9, Canada
E-mail address: trippele@mar.dfo-mpo.gc.ca

Paternal and maternal influences on early life history traits of haddock (*Melanogrammus aeglefinus*) were investigated in a crossing experiment of 5 males and 3 females producing 15 half-sibling families. Parental contributions to larval morphology (at day 0 and day 5 post-hatch) along with the time to starvation in the absence of food were analysed to explore parental effects on morphology, growth, yolk utilization and susceptibility to starvation. Maternal influence was evident for all morphometric traits examined, whereas paternal effects were only demonstrated for body size related traits (standard length and somatic area). Specific growth rate was subject to paternal and maternal influences, whereas yolk utilization efficiency was not subject to any parental influence. The time taken for larvae to die in the absence of food was affected only by maternity. Yolk area and time to starvation were not correlated. Results of this study support the hypothesis that maternity is more important than paternity in shaping larval morphology during the yolk-sac stage of temperate marine fish. However, paternity may influence up to 20% of total observed variation in larval traits and should be considered an important factor for early life history success.

Oral 46

GENETIC VARIATION AND SPAWNING PERFORMANCE AMONG RELATED AND UNRELATED SECOND GENERATION AQUACULTURE BROODSTOCK OF HADDOCK (*MELANOGRAMMUS AEGLEFINUS*)

Edward A. Trippel¹, Patrick T. O'Reilly², Rick M. Rideout^{1,3}, Stephen R.E. Neil¹, Lorraine C. Hamilton², Ellen Kenchington², Christophe M. Herbinger⁴, Christopher T. Taggart⁵

¹ Fisheries and Oceans Canada, Biological Station, St. Andrews, New Brunswick, E5B 2L9, Canada

² Fisheries and Oceans Canada, Bedford Institute of Oceanography, P.O. Box 1006, 1 Challenger Drive, Dartmouth, Nova Scotia, B2Y 4A2, Canada

³ University of New Brunswick, Department of Biology, P.O. Box 5050, Saint John, New Brunswick, E2L 4L5, Canada

⁴ Dalhousie University, Department of Biology, Halifax, Nova Scotia, B3H 4J1, Canada

⁵ Dalhousie University, Department of Oceanography, Halifax, Nova Scotia, Canada, B3H 4J1

E-mail address: trippele@mar.dfo-mpo.gc.ca

As wild finfish stocks decline throughout many of the world's oceans, interest in the culturing of selected species is increasing. In many marine species, the juveniles selected for grow out to produce the next generation broodstock are produced using communal spawning techniques, where 10's of males and females are placed into a single tank and allowed to spawn naturally. Male or female dominance in spawning success, coupled with reproductive variance and family-related differential early survival, can all markedly reduce genetic diversity over relatively few generations. Selection for particular traits of interest can further erode genetic variation, leading to increased levels of inbreeding in subsequent generations and overall inbreeding depression in the cultivated stocks. We present results from a haddock (*Melanogrammus aeglefinus*) breeding study designed to compare several indicators of genetic diversity, including observed and expected heterozygosity, allelic metrics, coefficients of co-ancestry and mean kinship among: 1) second generation aquaculture broodstock selected for size-at-age; 2) second generation aquaculture broodstock selected at random; and 3) haddock obtained from the wild. We also present data on the number of contributing adults and reproductive variance derived from a communal spawning experiment consisting of multiple males and females. Finally, we present results from a study designed to compare the number of egg batches produced from isolated spawning-pairs of reproductive full-sibs and isolated spawning-pairs of unrelated haddock. Our preliminary results indicate a rapid erosion of genetic diversity and large increases in rates of inbreeding.

Oral 47

REGULATION OF COD (*GADUS MORHUA*) REALISED FECUNDITY IN CONSTANT AND NATURAL PHOTOPERIOD REGIMES.

Peter Witthames¹, Anders Thorsen², Olav Sigurd Kjesbu²

¹ CEFAS Laboratory, Pakefield Road, Lowestoft Suffolk NR33 0HT, England

² Institute of Marine Research, P.O.Box 1870 Nordnes, N-5817 Bergen, Norway.

E-mail address: p.r.witthames@cefas.co.uk

This paper presents data to investigate the effect of continuous compared with natural photoperiod on realised fecundity and egg production processes applying the light regimes to 2 year-old cod, reared in captivity, just prior to the start of annual egg production. In the continuous photoperiod cod produced eggs earlier and at a faster rate compared with fish held in natural light. Measurements of egg diameter indicated that there was no overall significant difference ($P > .05$) in mean egg size produced by the populations in each photoperiod regime. In both males and females the GSI of fish killed at intervals during each experiment also indicated that egg production was faster but for a shorter duration in a constant photoperiod regime. Blood samples from these samples showed similar trends in levels of estradiol 17β and 11 keto testosterone in females and males respectively that corresponded to the changes in GSI. Vitellogenin levels in the blood also followed the changes in GSI even in males albeit at levels 1000 fold less than those found in females. Samples of the ovary were taken either by cannulation from the same female or by killing fish at intervals to study the dynamics of follicle development or regression (atresia) during the spawning season. In these samples the amount of atretic follicle production was assessed in relation to the proportion of eggs spawned.

Poster II-1

COD (*GADUS MORHUA*) MEAT COMPOSITION AND DIETARY RECOMMENDATIONS

Henrik Rosendahl Kristiansen
International Food Science Centre, Sønderkovvej 7, Dk-8520 Lystrup, Denmark
E-mail address: hrk@ifsc.dk

A Food Administration database was used to analyse how boiled and fried cod meat cover the nordic nutritional requirements (NNR) of humans. Protein quality was assessed using the Protein Digestibility Corrected Amino Acid Score (PDCAAS). It show how cod meat match the essential amino acid (EAA) requirements of 2-5 year old childs. The PDCAAS showed that phenylalanine is the first limiting EAA followed by tryptophan and histidin (not regarded as EAA to adults). Consequently, cod meat is not ideal protein, but the limiting EAA can be obtained from other food products. The analysis showed that a ration of 265 g cod cover NNR of all the EAA in adults. This ration would also satisfy 40% of the daily intake of n-3 fatty acids. However, since cod is a lean fish (<2 g fat 100 g-1), less than 6% of NNR for MUFA , PUFA and EFA (linoleic and alfa-linolenic acid) is covered. Although cod is not very rich in vitamins, the meal cover more than 50% of NNR for cobalamin, niacine and cholecalciferol, and 29-41% alfa-tocopherol and pyridoxine is covered. The fact that cod entirely cover NNR for selenium and iodine is a feature characteristic for seafood. Moreover, 265 g cod meat almost entirely (93%) cover the phosphorus requirement. The additional benefit from cod meat is that 23-31% of the magnesium and potassium requirement is covered. The results are discussed in relation to seafood and prevention of lifestyle diseases (obesity and CHD). One important issue is how farmed cod can be tailored to the seafood marked since wild Atlantic cod stocks are threatened. To answer this question thoroughly, it is necessary to understand how the meat composition of cod can be manipulated to fit the demand from the lifestyle concerned consumers, by changing the dietary composition of cod feed.

Poster II-2

EFFECT OF KRILL MEAL, HIGH IN FLUORIDE, ON COD QUALITY AND HEALTH, - NECESSARY ASSESSMENTS OF AN ALTERNATIVE PROTEIN SOURCE

Mari Moren (1), Mariann K. Malde (1), Rolf Erik Olsen (2), Lisbeth Dahl (1), Gro-Ingunn Hemre (1) and Kåre Julshamn (1)
(1) National Institute of Nutrition and Seafood Research (NIFES), pb 176 Sentrum, N-5804 Bergen, Norway
(2) Institute of Marine Research (IMR), Matre Research station, 5984 Matredal, Norway
E-mail address: mari.moren@nifes.no

As the access to traditional raw materials for the production of fish diets decreases, it is necessary to validate alternative raw materials' effect on both fish quality and fish health. Krill meal seems to be a high quality protein source, but contains fluoride in great concentrations (up to 6000 mg kg-1, dry wt). Fluoride is known to be toxic in mammals, affecting bone and teeth mineralization. Hence, for all animal household, a maximum limit at 150 mg kg-1 diet (dry wt.) has been set by the EU. This prevents the use of Krill meal as a protein source today. However, the fluoride from krill meal has been shown to have low retention in muscle of Atlantic salmon and rainbow trout, quite different from what is observed in mammals. It is therefore of interest to further study the retention of fluoride from krill meal in other aqua-cultured species. Furthermore, if this alternative feed resource shall be accepted for fish diets, possible negative effect on fish health caused by high krill meal concentrations in the diet must be addressed as well. In this study fish meal were replaced with krill meal (20 – 60%) in diets to cod in triplicates for 3 months. One diet without krill meal and one diet added 150 mg NaF kg-1 were used as control diets. Analyses of fluoride concentrations in the diets and soft tissues will be presented together with parameters on health status such as oxidative stress (the activity of super-oxid dismutase, catalase and glutathione peroxidase in liver) and blood parameters (haematokrit, haemoglobin, red blood cells, total protein and glucose).

Poster II-3

THE FATTY ACID CONTENTS IN THE MUSCLE AND LIVER OF WILD, FED-WILD AND FARMED ATLANTIC COD (*GADUS MORHUA*) AND ITS DEVELOPMENT OF RANCIDITY DURING STORAGE IN ICE OR IN SLUSH

Diep Mach¹ and Ragnar Nortvedt²

1)NIFES, PB 176 Sentrum, 5804 Bergen, Norway

2)Department of Biology, University of Bergen, High Technology Center, 5020 Bergen, Norway

E-mail address: ragnar.nortvedt@nifes.no

Wild cod (WC, n = 30, 2.45±1.02 kg) were caught outside Florø in Norway and fed wild cod (FWC, n = 30, 2.15±0.56 kg) and farmed cod (FC, n = 30, 3.13±0.67 kg) were collected from Nærøysund cod farm in Florø. The liver accounted for 6.6±3.1% in WC, 11.0±2.4% in FWC and 11.4±1.9% in FC. The level of fat in the fillet was 0.4% in the WC and 0.5% in the other groups. The fat contents in the liver amounted to 62.4±3.1 % in WC, 59.1±1.4 % in FWC and 64.7±2.1% in FC. The fatty acids (FA) in fresh fillet and liver and free fatty acids (FFA) in stored liver were determined at day 0 and after 6, 10 and 14 days of storage either in crushed ice (-2.2 to +1.2°C) or brine slush (-6.0 to -3.7°C). The development of oxidation (TBARS) of FA in the liver and fillet were recorded after 6, 10 and 14 days of storage in either ice or slush and after 17 and 21 days in the fillet stored in slush. Eleven FA (64% of the total fatty acids, TFA) in the fillet and 18 FA in the liver (75% of the TFA) showed significantly different distribution between the WC and the two other groups. Three FA (6%) in the fillet and in 12 FA (55%) in the liver were significantly different between the FWC and FC. The DHA (22:6n-3) and the EPA (20:5n-3) showed generally higher relative percentual levels in the fillet (45-49% TFA) than in the liver (18-23%). The lowest EPA value was recorded in the fillet of the WC, while in the liver there were insignificant differences. By contrast, the level of DHA in the liver of the WC showed the highest value, compared to the other groups. In the fillet, the WC showed the highest level when compared by percentual values but almost the same in mg/g of organ. The WC showed the lowest FFA values at day 6 and 14 in ice and at day 10 and 14 in slush. There was no significant difference in percentage of FFA at the same day between the two storage methods. For lipid-oxidation, the results showed that the TBARS value of the WC liver was higher than the others. The deviation of TBARS value between individuals was lesser when stored in slush than in ice. In conclusion, after 3.5 months of feeding, the FA component and the development of rancidity of the FWC differed from the WC and resembled the levels in the FC.

Poster II-4

COMPARATIVE LOSS OF QUALITY IN THE ATLANTIC COD, *GADUS MORHUA*, AND THE NILE PERCH, *LATES NILOTICUS*, DURING ICE OR SLUSH STORAGE

John Bosco Ahimbisibwe^{1,2} and Ragnar Nortvedt^{1,2}

1)NIFES, PB 176 Sentrum, 5804 Bergen, Norway

2)Department of Biology, University of Bergen, High Technology Center, 5020 Bergen, Norway

E-mail address: ragnar.nortvedt@nifes.no

Cod from Norway and Nile perch fillets from Uganda were stored either on ice or in slush for comparison of quality deterioration. Their quality was monitored at 0, 2, 6, 10, 14 and 21 days. The total plate count (TPC) and Hydrogen sulphide-producing bacteria were used as microbiological indicators. Total volatile base Nitrogen (TVB-N) and trimethylamine (TMA) production determined by the Conway microdiffusion method were used as chemical indices of quality. Preliminary results show a high plate count and hydrogen sulphide-producing bacteria in the Nile perch compared to the cod stored on ice. Storage in slush greatly inhibited bacterial growth as the TPC and hydrogen sulphide-producing bacteria were low compared to ice storage. Hydrogen-sulphide production in the Nile perch was found to be by *Aeromonas hydrophila* and was insignificant until later days of storage. TVB-N and TMA production increased with storage time. While fresh samples contained relative amounts of TVB-N, they did not contain TMA whose production occurs after days of storage. A comparison is made between cod and the Nile perch as well as between farmed and wild cod.

Poster II-5

COMPARATIVE QUALITY STUDY ON REARED AND WILD ATLANTIC COD (*GADUS MORHUA*) DURING STORAGE

Siri Smith^{1,2}, Marit Espe¹ and Ragnar Nortvedt^{1,2}

1)NIFES, PB 176 Sentrum, 5804 Bergen, Norway

2)Department of Biology, University of Bergen, High Technology Center, 5020 Bergen, Norway

E-mail address: ragnar.nortvedt@nifes.no

Three groups of experimental fish (n=15 x 3): farmed (Nærøysund fish farm), wild and fed wild were stored on ice for 14 days after slaughtering. Farmed and fed wild cod were fed EWOS Torsk 1200 pellets for three months prior to four days of starvation before slaughter. pH was measured (n=15 x 3) directly in the fillet, and TVB-N and TMA were measured (n=15 x 3) by the Conway method on day 1, 6, 10 and 14 during storage. Breakdown of muscular protein was examined by SDS-PAGE (Polyacrylamide Gel Electrophoresis), and concentration of glycogen in the muscle was measured using RA 1000, on day 1 and 14 (n=5 x 3). For all three groups the instant available energy resources were almost emptied from day 1, due to handling stress prior to slaughtering. pH showed a drop from day 1 to 6 due to breakdown of glycogen, followed by production of lactic acid. Increasing pH from day 10 to 14 happened when the amino acids started breakdown and produced ammonia. TVB- N (NH₃ + TMA) are the breakdown products of the amino acids and TMAO. These compounds are water soluble and were detected at low and decreasing levels during ice storage, probably got washed out of the fillet by the melting water from the ice. Number of bands in gels from SDS-PAGE from day 1 and 14 showed that no major difference occurred during this time interval. Breakdown of muscle protein were therefore not fully established during 14 days of storage for neither of the groups, with a consequently longer shelf-life than expected. From the results in the present investigation it is also given recommendations for future sample size due to statistical power analysis

Poster III-1

GENETIC ANALYSIS OF TEMPORALLY DIFFERENTIATED SPAWNING POPULATIONS OF ATLANTIC COD

Adrienne Kovach¹ and David Berlinsky²

1 Department of Natural Resources, University of New Hampshire, Durham, NH 03824, USA

2 Department of Zoology, University of New Hampshire, Durham, NH 03824, USA

E- mail address: Adrienne.kovach@unh.edu

In marine fish, the homogenous environment and absence of dispersal barriers favor interbreeding. Despite potentially high levels of gene flow, however, population structuring may exist. In Atlantic cod (*Gadus morhua*), genetically differentiated populations can persist in the absence of physical barriers or great distance. Additionally, population structuring has been linked with differences in migratory and spawning behavior. These recent findings suggest that cod do not interbreed freely, but rather aggregate into local reproductively isolated populations. In coastal New Hampshire waters, cod spawn during one of two distinct seasons; winter fish spawn October-December and spring fish spawn May-June. We have been studying aspects of cod reproduction using captive broodstock and were, therefore, interested in determining if these differences in spawning behavior were correlated with genetic differences. We used 7 polymorphic microsatellite DNA markers to genotype 48 spawning females sampled on the same spawning grounds, during each of the two spawning seasons. We found no significant genetic differentiation of the two spawning populations. The mean F_{ST} estimate over all loci was -0.0013. Our results indicate that, despite temporal differences in spawning behavior, the fish in coastal New Hampshire waters are genetically homogenous. Lack of genetic divergence suggests the two spawning populations are not reproductively isolated or may have been isolated only very recently. The ecological factors influencing the different spawning behaviors warrant further study. This work was supported by a grant from the Cooperative Institute for New England Mariculture and Fisheries (CINEMar).

Poster III-2

DOMESTICATION OF ATLANTIC COD, *GADUS MORHUA*, - GENETIC CHARACTERISATION OF BROODSTOCK COLLECTED FROM FOUR NORWEGIAN COASTAL COD POPULATIONS

Jørstad, K.E. *, Dahle, G., Rusaas, H. E. and Otterå, H.
Institute of Marine Research, Department of Aquaculture, Bergen, Norway
*Corresponding author K.E. Jørstad
Address: Post Box 1870 Nordnes, 5817 Bergen, NORWAY
E-mail: knut.joerstad@imr.no

The aquaculture industry in Norway is now focused on developing economically viable farming based on the Atlantic cod, *Gadus morhua*. Extensive research has been carried out for this species for the two last decades, much of it in connection with stock enhancement. Until now, most of the intensive cage culture has been based on wild cod as broodstock. However, a future cod aquaculture industry must be based on a domesticated broodstock, and the initial selection of wild cod in this process becomes an imported issue. Genetic differentiation between coastal cod populations has earlier been reported in Norway, and it was important to evaluate some of these populations under farming conditions. In spring 2002, alive, mature cod were collected at four selected spawning sites along the Norwegian coast (Porsangerfjord, Tysfjord, Herøy and Øygarden) during the spawning season. The fish was transported to the cod aquaculture facility west of Bergen, where they were kept in net pens. In late November the same year, individual tagging and extensive sampling (blood, white muscle and fin-clips) were carried out. Based on the samples collected, each fish were genotyped for haemoglobin, five allozyme loci, ten microsatellite loci and the Pan loci. Comparisons of allele frequencies (17 loci) revealed significant genetic differences between some of the coastal cod samples, and the performance of the offspring from the broodstock are now being compared under farming conditions. The microsatellite data have also been used to calculate the relatedness between all individuals, and minimum number of loci necessary to identify offspring from any parent combination

Poster III-3

GENETIC DIFFERENCES AMONG POPULATIONS OF ATLANTIC COD ALONG THE NORWEGIAN COAST AND THE BARENTS SEA REVEALED BY PAN I AND MICROSATELLITE LOCI

Tuula Sarvas, Jon-Ivar Westgaard and Svein-Erik Fevolden
Norwegian College of Fishery Science, University of Tromsø
E-mail address: tuulas@nfh.uit.no

Knowledge of genetic structuring of natural populations is important for new species in aquaculture. The cultured species should be genetically adapted to the local environment in which it will be farmed. Moreover, consequences for local stocks, if intermingled with escaped cultured fish of a different genetic origin, should be kept at a minimum. We have studied the genetic differences among populations of Atlantic cod (*Gadus morhua*) along the Norwegian coast and in the Barents Sea using the scnDNA pantophysin locus (Pan I) and eight microsatellite loci as markers. Our studies with Pan I have revealed a distinct genetic divergence between the inshore and offshore populations of cod in northern Norway. This difference is temporally stable and can be seen in all age groups of cod. The microsatellite studies support the Pan I data and in addition reveal significant structuring on a finer scale, e.g. between different fjords. We believe that the existence of genetically different breeding units is causing the observed structuring. The consequences of these findings should be taken into account in the planning of a cod aquaculture industry.

Poster IV-1

EFFECTS OF HYPOXIA ON GROWTH, HEALTH AND RISK OF VIBRIOSIS IN JUVENILE COD

Kathrine Ryvold Arnesen¹, Hilde Toften², Jan Eirik Killie¹
1 Norwegian College of Fisheries Science,
2 Norwegian Institute of Fisheries and Aquaculture Research
E-mail address: kathrira@stud.nfh.uit.no

Oxygen deficient water causes a variety of physiological responses in fish that might result in reduced growth, health and survival. Thus, it is always of great importance to the fish farming industry to avoid such limiting oxygen levels. We have examined the long-term effects of different oxygen saturations (45,65 and 85%) on feed intake, growth, physiology, health and risk of vibriosis (*Vibrio anguillarum* disease) in juvenile cod. Hypoxic conditions were obtained by partially replacing the dissolved oxygen with nitrogen. After 6 weeks exposure to the different oxygen conditions, fish were challenged with *Vibrio anguillarum* and followed for 5 weeks. Fish mortality was recorded throughout the experiment. At day 1, 42 and 84, length and weight of individually marked cod were measured. The feed intake of fish in each tank were recorded 3 times a week during the first 42 days. Samples of blood for analysis of ions, pH, PCO₂, glucose and hematocrit were taken from 12 fish from each group at day 0, 20 and 41. In the oxygen exposure period, the oxygen saturation was monitored several times every day. Water temperature were recorded daily. Other water parameters (flow, water current, total gas saturation, pH, CO₂, etc.) were also examined regularly. Preliminary results show reduced feed intake and growth with decreasing oxygen saturation. At day 42, some fish subjected to the lowest oxygen saturation seemed fragile and had skin hemorrhages, but mortality was relatively low in all groups during the oxygen exposure period. After the viral challenge, mortality was high, but it remains to conclude whether oxygen deficiency increase the risk of vibriosis.

Poster IV-2

GENETIC VARIATION IN RESISTANCE AGAINST VIBRIOSIS IN ATLANTIC COD (*GADUS MORHUA*)

Anne Kettunen¹, Madjid Delghandi², Merethe Aasmo Finne², Øyvind J. Hansen², Lise Haug², Atle Mortensen², Katrine Skajaa², Mette S. Wesmajervi² and Kjersti T. Fjalestad²
1 Norwegian College of Fishery Science
2 The Norwegian Institute of Fisheries and Aquaculture Research
E-mail address: annehk@nfh.uit.no

Disease outbreaks in aquaculture result in great economic losses in form of high medical costs, high mortalities, increased labour, as well as low product quality and poor consumer acceptance. Consequently, disease resistance is usually seen as one of the main breeding objectives in selective breeding programmes for various aquatic species. Survival data from controlled challenge tests are used as selection criteria, and have been found to be an effective tool for genetic improvement of disease resistance. Nevertheless, it is not apparent which diseases potentially are the most hazardous for cod aquaculture. Due to the prevalence of the disease, together with readily available challenge test protocol for cod juveniles, classical vibriosis was chosen as target disease for the first challenge test. The Norwegian Institute of Fisheries and Aquaculture Research in Tromsø has recently initialised a breeding programme for cod. Last year a total of 24 families were produced. In this experiment, 20 full-sib families, out of which 13 represented Norwegian coastal cod and 7 northeast Arctic cod, were tested for survival after challenge with *Vibrio anguillarum*. Families comprised of 30-50 PIT-tagged fish of 20-150 g of weight, and 9-10 months of age, and represented the first year class of the breeding programme population. Before starting the test, fish were allowed to acclimatise in a common tank to the temperature of 10 °C. Fish were challenged by immersion with *V. anguillarum* for 60 minutes by adding 50 ml of bacteria culture in the tank; a dosage corresponding 1.1 x 10⁵ CFU per ml of tank water. Mortality after challenge was recorded daily, and when the experiment was terminated, survival rates in different families were estimated. Detailed description of the experimental design together with the final results will be presented at the meeting.

Poster IV-3

CHARACTERISATION OF VIBRIO SPECIES IN DEVELOPING COD LARVAE BY DGGE.

Helen I. Reid and T. Harry Birkbeck, University of Glasgow
E-mail address: helenr@mblab.gla.ac.uk

The microflora of developing larvae is known to be an important factor affecting larval health and survival. Whilst most changes in the microbiota appear to be associated with dietary changes, the occurrence of some species in the gut microflora appears to be transient, whereas others can persist for longer periods. *Vibrio* species are abundant in marine ecosystems and, being fast growing opportunists, are often early colonisers of the digestive tract of marine animals. As several species are associated with disease in aquaculture, there is a need to be able to readily identify vibrios in the gut microflora. We have applied molecular methods to monitor the microflora of cod larvae, using denaturing gradient gel electrophoresis (DGGE). DGGE of 16S rDNA PCR products is widely acclaimed as a powerful tool for analysis of mixed microbial communities but the high degree of relatedness of vibrios means that commonly applied universal primers do not discriminate easily between species. An alternative target for PCR is the RNA polymerase beta sub-unit gene, which displays more variation than 16S rDNA. Here, we describe primers designed to amplify a 340bp portion of the *rpoB* gene of vibrios. Upon DGGE, PCR products from type strains and cod larval gut isolates migrate as single bands with clear discrimination between species. This has allowed us to characterise vibrios from the developing gut of aquaculture-reared cod larvae. *Vibrio* species constituted a large proportion of the microflora after larvae have been weaned off rotifers and started feeding on *Artemia* (day 25 approx.). *Vibrio alginolyticus* was predominant until larvae moved onto dry feed, when *V. splendidus* became dominant. Other species could be found at lower levels including *V. anguillarum* and *V. xuii*.

Poster IV-4

PARASITES AND PREDATORS IN COD-AQUACULTURE

Ivar H. Pettersen
Department of Fisheries and Science, Nordland Regional University Bodø, Norway.
E-mail address : Ivar.H.Pettersen@hibo.no

A few of the common parasites of wild cod are starting to unveil their harmful abilities to cod aquaculture (CA). Some other parasites that up to present have been considered potentially dangerous to CA, may be possible - even easy - to avoid. Predators such as hungry cormorants, seals, otters and huge wild cods, may also be a big nuisance. The general impression is that cultured cod have an extremely low infection rate of nematodes, very different from wild cod. *Cryptocotyle lingua* (C.I.) causes the black-spot-disease (BSD), which is extremely common on most fish-species visiting rocky shores during summer. Where artificially cultured cod-spat are raised in such areas, this may be a big problem. The larvae (cercaria) of C.I. leave their intermittent host, the snail (*Lithorina*), when the temperature exceeds 8-9 degrees C. The fillet of cultured cod, if heavily infested with larvae of C.I. during the cods first summer, will remain very spotty even years after infection. This probably will be a disadvantage on the market. On bigger cods however, most larvae will not penetrate the skin and there will be few black spots on the fillets. *Lernaeocera branchialis* is known as the most fatal cod-parasite of the Atlantic. If 0+ group cod is placed at locations with flounders (intermediate host) too early in the summer/autumn, the 0+ cod may be infected and the mortality will be close to 100 %. This suggests that shallow areas with sandy seabed may not be the best location for CA. The blood-parasite *Trypanosoma murmanensis* in combination with *L. branchialis* causes near 100 % mortality even in big cod. *Anisakis simplex*, also a very common parasite in wild cod, is seldom seen in CA. We have so far not observed *Pseudoterranova* in CA. *Caligus curtus* and *C. elongatus* (the sea-lice) might become problems, especially late in summer and autumn; problems not seen so far.

Poster IV-5

CHARACTERISATION OF BACTERIAL COMMUNITIES ASSOCIATED WITH CULTURED COD LARVAE BY MEANS OF DENATURING GRADIENT GEL ELECTROPHORESIS (DGGE) OF PCR-AMPLIFIED 16S rDNA

Laila Brunvold^{1,2}, Ruth-Anne Sandaa^{1, 2}, Helene Mikkelsen³, Eirik Welde⁴, Hogne Bleie⁵, and Øivind Bergh²

¹ Department of Biology, P.O. Box 7800, University of Bergen, N-5020 Bergen, Norway

² Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway

³ Norwegian Institute of Fisheries and Aquaculture, P.O. Box 6122, 9122 Tromsø, Norway

⁴ Troms Marin Yngel, Kraknes, N-9100 Kvaløysletta, Norway

⁵ National Veterinary Institute, PO Box 1263, N-5811 Bergen, Norway

E-mail address: ovind.bergh@imr.no

Intensive hatcheries, high mortalities are often experienced, particularly during the first feeding stages when larvae are fed rotifers or Artemia. We have sampled cod larvae from three different hatcheries in Norway (hatchery A, B and C). In two of these hatcheries, B and C, high mortality was experienced in several larval batches. The bacterial communities of healthy and unhealthy cod larvae, isolated from the different hatcheries, were analysed by Denaturing Gradient Gel Electrophoresis (DGGE) of PCR-amplified 16S rDNA followed by excising and sequencing bands. Comparison of the bacterial communities isolated from cod larvae from two different larvae tanks in the hatchery A, indicate a shift in community composition before or when the cod larvae are fed, and differences were found that could possibly be correlated to larval survival.

Poster IV-6

JUVENILE ATLANTIC COD MORTALITY AND HEALTH ISSUES: A CASE STUDY FOR NEWFOUNDLAND AND LABRADOR.

Velmurugu Puvanendran¹, Danny Boyce¹, Lori Thorne¹, Manjusri Wijekoon¹, Joseph A. Brown¹ and Daryl Whelan²

¹ Aquaculture Research Development Facility, Ocean Sciences Centre, Memorial University, St. John's, Newfoundland, Canada A1C 5S7

² Newfoundland and Labrador Department of Fisheries and Aquaculture, Fish Health Section, P.O. Box 8700, St. John's, NL, A1B 4J6

E-mail address: Puvy@mun.ca

Piscine nodavirus are known to cause Viral Encephalopathy and Retinopathy (VER) or Viral Nervous Necrosis (VNN) in cultured marine fish species. In recent years, Atlantic halibut, Atlantic cod, and haddock have known to be affected by this disease in the Northeast Atlantic. In September 2002, juvenile Atlantic cod cultured at the Aquaculture Research and Development Facility (ARDF) of the Ocean Sciences Centre tested positive for nodavirus, this was the first confirmed case in Newfoundland. Higher water temperature (~ 16°C) and subsequent external parasitic infection could have stressed the juveniles sufficiently to make them susceptible to nodavirus infection. Juveniles in some tanks showed no clinical symptoms while juveniles in other tanks exhibited erratic swimming behaviour, loss of appetite and eventual death. Both of these groups, however, did test positive for nodavirus. The majority of cod produced in 2002 were culled. Some of the juveniles that tested negative were kept at a production site and are being closely monitored. In 2003, we implemented strict biosecurity measures and had better temperature control, which resulted in a record production of healthy cod juveniles. The results on the importance of minimizing stress and the need for strict biosecurity measures will be discussed.

Mode of presentation : poster.

Poster IV-7

THE PARASITE FAUNA OF EUROPEAN HAKE (MERLUCCIIUS MERLUCCIIUS) IN WESTERN NORWAY

Cecilie F. Myklebust
Fjord-Lab AS, Måløy, Norway
E-mail address: cflmykle@online.no

An examination of 154 hakes, mainly from two sites in W Norway, revealed many different parasites. The aim of the study was to characterize the parasite fauna of hake in coastal waters before its potential future culture. A total of 44 parasite species were detected and 6 of these species are considered as common. Rare parasites represented 18 species. Several new host records were made, one of these was *Parvicapsula unicornis* Kabata, 1962. In general, metazoan ectoparasites of hake are merlucciid specialists, while most endoparasites are generalists or shared with gadidae. A total of 11 species of ectoparasites were identified. Some ectoparasites are predicted to become harmful in future aquaculture of hake.

Posters IV-8

EFFICACY OF ORALLY ADMINISTERED FLUMEQUINE IN TREATMENT OF VIBRIOSIS IN ATLANTIC COD, *GADUS MORHUA*

Frode Vik-Mo¹, Ole Bent Samuelsen² and Øivind Bergh²
¹ University of Bergen
² Institute of Marine Research, Bergen, Norway
E-mail address: frode@vik-mo.org

This study was performed in order to investigate the efficacy of orally administered flumequine to treat experimentally induced vibriosis in cod (*Gadus morhua*). Twelve groups, each containing 40 fish, were bath challenged for 1 hour with *Vibrio anguillarum*, serotype O2 (HI-610). Three days following challenge, medication of flumequine was introduced in ten of the groups. Ten groups were given a daily drug dose of 2.5, 5, 10, 15 and 25 mg/kg fish per day (two replicate groups per dose), and two unmedicated groups were included to determine the mortality in absence of treatment. The experiment was terminated after two weeks. Plasma, muscle and liver samples were collected from three fish in each group. HPLC was used to determine the concentration of flumequine. The minimum inhibitory concentration, with both 2% NaCl and seawater (salinity 30 ppt) in the media, was determined for 20 pathogen strains of *Vibrio anguillarum*. Results will be presented at the conference.

Posters IV-9

PHYSIOLOGICAL STRESS RESPONSES IN HADDOCK (*MELANOGRAMMUS AEGLEFINUS*): CORTICOSTEROIDS, PLASMA GLUCOSE AND HEAT SHOCK PROTEINS.

Luis O. Afonso¹, Steve Leadbeater¹, Kurt Gamperl², Stewart C. Johnson¹ and George K. Iwama¹
1. Institute for Marine Biosciences, National Research Council, Halifax, NS B3H 3Z1
2. Ocean Science Centre, Memorial University of Newfoundland, St. John's, NF, Canada A1C 5S7
E-mail address: Luis.Afonso@nrc-cnrc.gc.ca

Exposure to stressors such as extremes in water temperature, handling, confinement and poor water quality are known to cause a generalized stress response in a variety of species of fish. Little is known about the stress response of gadoids. We are examining the stress response of juvenile haddock exposed to handling (30 sec to 1 min out of water), anaesthetic and heat shock (rapid 5°C increase for 1 hour) at a variety of environmental temperatures 5, 10 and 15°C. Levels of plasma cortisol and glucose as well as tissue heat shock protein 70 (HSP70) expression are being determined prior to and at a variety of times post-stress. Pattern and magnitude of plasma cortisol levels varied with temperature. High variation in plasma cortisol levels among individuals within the same treatment were also observed (clearly “low and high responder” fish can be identified). Maximum plasma cortisol levels were seen at 1 h after the stressors had been applied, and at 3 h the levels were already returning to basal values. Unlike salmonids, exposure to these acute stressors did not elicit an elevation of plasma glucose in haddock. Low levels of constitutive HSP70 production were identified in gill tissue but not in liver of haddock exposed to heat shock. There was no evidence of cellular stress response in any of these tissues as indicated by a lack of inducible HSP70 production. Our results indicate that some aspects of the haddock response to stress differ from salmonids. Whether these responses are shared with other gadoids is presently being investigated for Atlantic cod under the same experimental conditions.

Posters IV-10

PARASITE FAUNA OF THE ALIMENTARY TRACT AND THE BIOCHEMICAL PARAMETERS OF LIVER AND MUSCLES OF COD, *GADUS MORHUA* FROM THREE DIFFERENT LOCATIONS

Ewa Sobecka¹, Beata Wiecek² and Magdalena Wielopolska³
1,2,3 University of Agriculture. Szczecin, Poland, Faculty of Food Sciences and Fisheries.
1. Dep. of Fish Diseases, 2. Dep. of Fish Systematics, 3. Dep. of Aquaculture
E-mail address: wienca@fish.ar.szczecin.pl

The present paper was aimed at estimating the geographical variation in parasite community structure among the populations of the same host species. A correlation between the basic parasite infection parameters (abundance and species composition) and the parameters of liver and muscles of cod (condition factor, dry weight, contents of lipids, proteins and ash) was determined. The samples of cod for this study were captured in the Barents Sea (73°30'N, 19°00'E, depth of 300 m, April 2002, n = 50 specimens), off the southeastern coasts of Iceland (63°25'N, 13°07'W, depth of 350–400 m, December 2001, n = 40), and in the south-western Baltic Sea, at the Kołobrzeg-Darłowski fishing ground (ICES SD 25, 54°31'N, 15°02'E, depth of 41 m, March 2002, n = 50). The average weights of the cod studied were as follows: 619.55 g (Barents Sea), 1854.97 g (coast of Iceland), and 608.0 g (Baltic Sea). The total length covered the range of 33.0–48.2 cm, 47.5–69.5 cm, and 29.5–48.3 cm, respectively. The most prevalent and abundant were acanthocephalans, nematodes, and digeneans found in the alimentary tract of cod. *Echinorhynchus gadi* (Acanthocephala) were recorded in cod from all sampling locations. Nematode parasites were also found in fish from all areas, however, their species composition and abundance differed markedly. Digenean parasites were recorded only in cod from the Barents Sea. The highest average number of parasites in fish, amounting to 102.2, was found in cod from the southeastern coasts of Iceland. Nematodes predominated (94.8 on average in one cod) in the structure of infection. The second largest average number of parasites in fish was noted in cod from the southern Baltic. It amounted to 92.4, of which *Echinorhynchus gadi*—being the most abundant acanthocephalan species—accounted for 92.1. The lowest number of parasites (38.6) was recorded in cod from the Barents Sea. In this number, digeneans were predominant parasites and they were represented by 18.9 inds./fish. The contents of lipids and dry weight in the muscles and liver turned out to be the lowest in cod from the Baltic Sea, where *Echinorhynchus gadi* was the most abundant. Similarly, the lowest level of lipids (17.06%) was also recorded in the muscles of Baltic cod. On the other hand, the lowest content of lipids in the liver was stated in fish where the digenean parasites were the most numerous. The hepatosomatic index, calculated for eviscerated fish, amounted to 3.76, whereas for cods with the highest intensity of infection is amounted to 5.06.

Posters V-1

SOME FACTORS AFFECTING THE EARLY FEEDING SUCCESS OF WALLEYE POLLOCK (*THERAGRA CHALCOGRAMMA*) LARVAE

Steven M. Porter, Kevin M. Bailey
NOAA, Alaska Fisheries Science Center;
E-mail address: steve.porter@noaa.gov

Small-scale rearing of marine fish larvae is necessary to examine various aspects of their development, behavior, and physiology. Manipulations of light, temperature, prey type and density, first exposure to prey, and turbulence are examined here as factors to improve the early feeding success of walleye pollock (*Theragra chalcogramma*) larvae reared in the laboratory. Studies have shown that light level and quality are important factors in feeding. We examined the effect of ultra-violet (UV) light on early pollock feeding; preliminary results indicate that exposure to UV light (from full spectrum fluorescent light bulbs at a light level of 2.3 micro-mol photon m⁻² s⁻¹) increased the feeding success of pollock larvae. Temperature and prey density also are important factors in feeding success. Pollock larvae reared at 6 degrees C had nearly twice the number of prey in their gut than those reared at 2 degrees C, and were most successful feeding at the highest prey density offered to them. Growth rates of larvae are correspondingly higher at high prey densities and temperatures. Growth rates also varied depending upon the prey type used. Turbulence may increase contact rates between predator and prey, but our results are inconclusive as to whether it has any measurable effect on feeding success. As well, larvae exposed to prey prior to first feeding do not feed any better than those that were first given prey at first feeding.

Poster V-3

GROWTH, SURVIVAL AND FEED CONVERSION EFFICIENCY OF POST-METAMORPHOSED ATLANTIC COD (*GADUS MORHUA*) REARED AT DIFFERENT TEMPERATURES

Linda J. Kling, Jennifer Muscato, Adrian Jordaan,
207 Rogers Hall, School of Marine Sciences, University of Maine,, Orono, Maine 04469, USA
E- mail address: lkling@maine.edu

Two growth trials were completed on post-metamorphosed Atlantic cod (*Gadus morhua*) for a period of four weeks each to determine the optimal temperature for best growth and feed conversion. The same experiment was repeated two times under the same conditions to determine the effect of four temperature regimes (10, 12, 14 and 16 C) on ungraded juvenile cod. Each treatment consisted of four replicate 75 L black tanks stocked with 287-300 juveniles/tank. The fish were fed to satiation three times daily on the commercial diet BioKyowa C (1 or 2 mm pellet size). Dead fish were counted daily but survival was determined by the number of cod surviving at the termination of the experiment, allowing cannibalism to be taken into account. Weight was measured biweekly. Post-metamorphosed cod grown at 14 and 16 C were significantly larger at the end of the experiment than the fish grown at 10 or 12 C ($p < 0.05$). Specific growth rate was significantly higher at 14 and 16 C than at the lower temperatures ($p < 0.05$). Fish held at 16 C utilized feed less efficiently than those held at the lower temperatures. Feed was used most efficiently by fish held at 10 C ($p < 0.05$). The lower feed efficiency at 16 C, and the low SGR at 10 and 12 C, suggest that within the range of temperatures studied, 14 C is the optimal temperature for best growth with good feed conversion.

Poster V-4

ESSENTIAL FATTY ACID DYNAMICS AND LARVAL PERFORMANCE IN COD (*GADUS MORHUA* L.)

Christopher Cutts¹, Jarin Sawanboonchun², Carlos Mazorra de Quero¹, John Gordon Bell²
¹ Scottish Association for Marine Science, Ardtoe Marine Lab., Ardtoe, Acharacle, Argyll PH36 4LD, U.K.
² Institute of Aquaculture, University of Stirling, Stirling FK9 4LA, U.K.
E-mail address: Christopher.Cutts@sams.ac.uk

One of the major bottlenecks to cod culture remains the provision of nutritionally adequate live feed. Moreover, inadequate diet in terms of essential fatty acid (EFA) content is one of the key reasons cited for poor larval performance. This study therefore presents data on the performance of replicated cod rearing tanks fed rotifers and *Artemia* under three different enrichment regimes. The fatty acid profiles of the three experimental diets and the larvae fed the diets was assessed and related to survival, growth and swimbladder inflation. Furthermore, the levels of incorporation of docosahexaenoic (DHA), eicosapentanoic (EPA) and arachidonic acid in larval somatic tissue relative to their amounts in both rotifers and *Artemia* from the dietary treatments was assessed, tracked through time and related to larval performance. The dynamics of both DHA and AA changed over time, between prey items and dietary treatments. During the rotifer phase, larvae from each treatment were able to incorporate comparable levels of DHA irrespective of levels in the diet. Despite this, the rotifer diet with slightly more DHA still promoted growth in those larvae. Conversely, larvae from two of the dietary treatments did not exhibit any incorporation of AA, instead reflecting levels found in the diet. Levels of both DHA and AA improved growth during the rotifer period, but ratios against EPA had no effect. During the *Artemia* phase, percentage levels of larval DHA markedly decreased; there was no incorporation of DHA relative to dietary levels, which in *Artemia* were significantly lower than in rotifers. However, elevated levels of DHA in larvae at the end of the experiment correlated well with survival. Regarding AA, larvae were able to incorporate levels comparable to the rotifer phase from the lower levels present in the *Artemia*. This also differed significantly between treatments, and correlated positively with survival. The study clearly shows how availability and incorporation of EFA's changes markedly in the first two months post-hatch.

Poster V-5

THE EFFECTS OF NUCLEOTIDE-ENRICHED BROODSTOCK DIET ON FIRST FEEDING SUCCESS AND SURVIVAL OF HADDOCK (*MELANOGRAMMUS AEGLEFINUS* L.) LARVAE

Jose L. Gonzalez-Vecino*^{1,2}, Christopher J. Cutts¹, Robert S. Batty², Paul L. Greenhaff³ and Simon Wadsworth⁴
¹ Scottish Association for Marine Science, Ardtoe Marine Laboratory, Ardtoe, Acharacle, Argyll, PH36 4LD, Scotland, UK.
² Scottish Association for Marine Science, Oban, Argyll, PA37 1QA, Scotland, UK
³ Centre for Integrated Systems Biology and Medicine, School of Biomedical Sciences, Nottingham University Medical School, Queen's Medical Centre, Nottingham NG7 2UH, UK
⁴ EWOS Innovation, 4335, Dirdal, NORWAY
E-mail address: Christopher.Cutts@sams.ac.uk

Broodstock nutrition is important for fish reproduction as it affects egg quality and larval performance. Nucleotides promote intestinal cell differentiation and maturation in mammals. Increasing availability of dietary nucleotides (NT) improves growth, osmoregulation, disease resistance and increases the intestinal surface area of Atlantic salmon. Haddock, a cold-water marine species, can suffer from poor larval performance but shows high potential for North Atlantic aquaculture. Therefore, NT-diet may have a beneficial effect on yolk-sac larvae during gut development. This study aims to investigate whether a NT-enriched diet given to haddock broodstock has beneficial effects on the first feeding success and survival of their progeny. Egg batches were obtained from broodstock fed either a NT-enriched or a control diet. Yolk sac larvae from both diets were incubated under the same conditions. Once larvae had started feeding, gut development, first-feeding success, survival and morphometrics of larvae from both dietary treatments were assessed. First feeding success in NT larvae was significantly higher and their survival was over 30 % greater. Larvae from the NT treatment were bigger and gut development was significantly more advanced than those from the control. Other findings related to the NT content of haddock larval samples are also discussed.

Poster V-6

EFFECTS OF INCLUDING LIPOSOMES AND ENZYMES IN FORMULATED START FEED FOR COD LARVAE.

Silja Karlsen¹, Hans Kristian Strand² and Inger-Britt Falk-Petersen¹
1 Norwegian College of Fisheriscience;
2 Holmfjord Sjøfarm AS;
E-mail address: siljak@nfh.uit.no

Cod larvae were fed on rotifers and either standard formulated feed without additives (SF), standard-feed with addition of liposomes (SFL) or standard-feed with addition of enzymes (SFE) in 700 l fiberglass tanks for 49 days at 12°C. Total average growth rate was 8,5% in the SFL-group, 8,2% in the SFE-group and 8,1% in the SF-group. The results indicate that addition of liposomes and enzymes to formulated start-feed may enhance the availability and absorption of essential nutrients in cod larvae.

Poster V-7

EFFECT OF ENRICHED ROTIFERS ON THE GROWTH AND SURVIVAL OF ATLANTIC COD (GADUS MORHUA) LARVAE.

Heum Gi Park¹, Velmurugu Puvanendran², Anne Kellett², Christopher C. Parrish² and Joseph A. Brown²
1 Faculty of Marine Bioscience & Technology, Kangnung National University, Kangnung, South Korea 210-702;
2 Ocean Sciences Centre, Memorial University, St. John's, Newfoundland, Canada A1C 5S7
E-mail address: Puvy@mun.ca

The nutritional requirements of marine finfish larvae have received major attention in the recent past and studies have shown that docosahexaenoic acid (DHA) affects the growth and survival of some marine finfish larvae. We carried out an experiment to investigate the effects of different rotifer enrichments containing variable amounts of DHA on the growth and survival of Atlantic cod larvae. Rotifers were enriched with enrichment diet 1 (ED1; DHA 43.8% of total fatty acids), enrichment diet 2 (ED2; 51.1%), enrichment diet 3 (ED3; 24.2%) and enrichment diet 4 (ED4; a mixture of ED1 and Chlorella at 7:3 ratio). Twelve 30 L aquaria were used as experimental tanks with three replicates per treatment. Larvae were fed with rotifers from 3 to 43 days post-hatch (dph) at 4000 prey L⁻¹ and the rotifer concentration was adjusted four times a day. At the end of the experiment, no significant difference was found in length and dry weight of the larvae reared on ED1 and ED2. However, larvae reared on ED3 were significantly smaller (both in length and weight) than larvae reared on ED1 and ED2. Larval survival was not significantly different between any treatments, however when an outlier from the ED2 treatment was removed, larval survival on the ED2 treatment at 43 dph was significantly higher than on the other three treatments. Our results showed a positive effect of DHA levels in the diet on growth and survival of cod larvae and demonstrated that Atlantic cod larvae require a high level of dietary DHA.

Poster V-8

FEED INGESTION ESTIMATED IN JUVENILE COD BY INERT LANTHANIDE MARKERS - PREFERENCE AND AVAILABILITY OF FEED PARTICLE SIZES.

Oddvard Garatun-Tjeldstø¹, Håkon Otterå², Kåre Julshamn³, Erland Austreng⁴

1 University of Bergen, Dept. of Molecular Biology, Thormøhlensgt. 55, N-5020 Bergen, Norway.

2 Institute of Marine Research, POB 1870 Nordnes, N5817 Bergen, Norway.

3 Directorate of Fisheries, Institute of Nutrition, POB 185 Sentrum, N-5084 Bergen, Norway

4 Disease 2003. Institute of Aquaculture Research (AKVAFORSK), POB 5010, N-1432 Ås, Norway

E-mail address: Oddvard.Garatun-Tjeldsto@mbi.uib.no

Development of formulated starter diets and improvement of diets for juvenile marine fish species is a major problem in aquaculture. The ingestion rate may be regarded as a parameter for evaluating if a diet particle is available, recognised, of adequate size, palatable and preferred by small fish. In this study we evaluated the effect of feed particle size on ingestion rate in juvenile cod. Lanthanide oxides were used as marker tools. Fish-meal based pellets were produced (with one marker in each), crushed, and the granulates were sieved into size-classes. Several multi-labelled diets were produced by combination of the mono labelled size classes. And each combination was fed for 1, 4, or 7 days to populations of juvenile cod in separate tanks. After termination by an anaesthetic, the fish were collected, individually weighed and frozen until analysis. The amount of lanthanides in homogenized fry was measured by Inductive Coupled Plasma Mass-Spectrometry (ICP-MS). The zero hypothesis (there is no preference for ingestion of any of the markers) could not be rejected. Thus the markers La₂O₃, Nd₂O₃, Dy₂O₃, Yb₂O₃ may be used as an inert non-biasing tools not acting either as repellents or attractors. The total intake of a multi-labelled dry diet was about 13mg per gram bodyweight, not dependent upon the size of the fish. We did not find a linear relationship between body weight and the optimal diet particle diameter which had given the highest intake. The ratio of optimal particle size related to bW was 4-6 micrometer/mg at bW below 200mg, 1,7- 2,4 micrometer/mg at bW around 500mg and 1-1,2 micrometer/mg at bW of 1000mg. The multi-labelled diets were combined on an equal weight basis, and larger particles have higher sinking rates. Thus the results should also be discussed in terms of feed availability rather than preference.

Poster V-9

BACTERIA IN THE GUT OF JUVENILE COD FED ROTIFERS ENRICHED WITH FOUR DIFFERENT COMMERCIAL DIETS

Kjetil Korsnes^{1,3}, Ove Nicolaisen², Øivind Bergh³, Cecilie Skår³, Audun Nerland³.

1. Bodø Regional University, N-8049 Bodø, Norway

2. Nordland Research Institute, N-8049 Bodø, Norway

3. Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway

E-mail address: kjetil.korsnes@hibo.no

Production of cod juveniles involves using live feed rotifers, which are enriched to provide nutrients to the larvae. The aim of this study is to quantify and characterise bacterial growth in the larval gut comparing effects of four commercial rotifer enrichments. Bacteria were isolated and grown on Tryptonic Soya Broth agar and Marine Agar and quantified as colony forming units (CFU) per larvae. Twenty juveniles from each enrichment group were surface disinfected and homogenised to expose the bacteria in the gut. Dominating strains according to colony morphology were characterised by PCR amplification and sequencing of a 16S rDNA product, and strain identities were established by searching for nucleotide-nucleotide matches in the BLAST database at the NCBI homepage. Two of the enrichment diets resulted in significantly higher CFU's, ranging between 10 to 100 times compared to the group with lowest CFU's. This was consistent for all samples analysed, and probably reflected the bacterial growth observed from the enrichment diet itself. CFU's were higher on Marine Agar than Tryptonic Soya Broth Agar.

Poster V-10

INVESTIGATION OF LIVE FEED DYNAMICS IN COD (*GADUS MORHUA*) LARVAE TANKS USING AN AUTOMATIC PLANKTON COUNTER

Morten Alver¹, Torodd Tennøy², Gunvor Øie³ and Jo Arve Alfredsen¹

1. Department of engineering and cybernetics

2. Thelma AS

3. SINTEF Fisheries and Aquaculture

E-mail address: Gunvor.Oie@sintef.no

The density of rotifers in cod tanks in the live feed period shows considerable temporal variation due to larval ingestion and water exchange, that rapidly reduce the density after each feeding. The goal of this study has been to quantify the rotifer density variation as experienced by the fish larvae in a typical rearing environment. An automatic rotifer counter based on image processing, with the ability to monitor the live feed dynamics efficiently over extended periods of time, was developed for this purpose. Liquid samples are extracted from one tank at a time, while cycling through a predetermined number of tanks. Repeatedly, the contents of a known volume of water are scanned by a high resolution digital camera. Each image is analyzed with regard to the number of particles of approximately the correct size and shape for rotifers. The counter operates autonomously and can produce measurements with a sampling interval of less than 5 minutes. The counter has been tested in rotifer densities common in both fishtanks and rotifer cultivation tanks. In this study, the properties of the device are demonstrated by measuring the dynamics of the rotifer density throughout the rotifer period in two tanks subjected to different feeding regimes. It is expected that this instrument will give new possibilities both for researchers and commercial users. Besides giving valuable immediate information on the feed density in larval tanks, it can be combined with automatic feeding equipment in order to control the feed availability. It is also planned to use the instrument in combination with a mathematical model in order to estimate larval feed intake and total larval biomass.

Poster VI-1

THE IMPORTANCE OF ENVIRONMENTAL VARIABILITY FOR NORTH SEA COD REARED FOR RESTOCKING

Victoria A Braithwaite¹ & Anne G V Salvanes²

¹Institute of Cell, Animal, and Population Biology, School of Biological Sciences, University of Edinburgh, EH9 3JT, UK.

² Department of Biology, University of Bergen PO Box 7800, N-5020 Bergen, Norway

E-mail address: Anne.Salvanes@ifm.uib.no

Fish populations can collapse through the absence of proper management and after over-exploitation and prolonged declines they recover slowly, if at all. A possible solution is to re-establish fish stocks with ocean farming and release of hatchery reared early life stages, a strategy used to restore lake populations of freshwater and salmonid species all over the world since the industrial revolution. But despite this long history, attempts at ocean ranching and releases of reared fish have had little success. Released hatchery fish die younger than wild fish to such an extent that releases do not elevate fish biomass. A possible reason for this high mortality may be that suitable behaviour cannot develop in the artificially homogeneous hatchery environment. It is well known for intelligent species in captivity that a low-stimulus environment results in cognitive deficits. In this presentation, we will show empirically, for North Sea cod (*Gadus morhua*), that the uniform environments of fish farms generates deficits in cognitive traits that can reasonably be expected to be associated with survival in the wild.

Poster VI-2

EFFECTS OF CHRONIC AMMONIA EXPOSURE ON GROWTH IN JUVENILE ATLANTIC COD

Sten I. Siikavuopio 1, Bjørn-Steinar Sæther 1 & Atle Foss 2
1 Norwegian Institute of Fisheries and Aquaculture Research, Tromsø N-9291, Norway
2 Akvaplan-niva, Bergen Office, Nordnesboder 5, N-5005 Bergen, Norway
E-mail address: sten.siikavuopio@fiskeriforskning.no

The effects of chronic un-ionised ammonia (UIA) exposure on growth and food conversion efficiency in juvenile Atlantic cod, *Gadus morhua*, were examined. Fish with a mean (SD) initial weight 16.7 (3.4) g, were exposed to four concentrations of UIA, ranging from 0.0006 mg l⁻¹ (control) to 0.18 mg l⁻¹, for 96 days at 13°C. Compared to the control, growth was significantly reduced at UIA concentrations above 0.06 mg l⁻¹, but the fish experiencing the most severe UIA concentrations still maintained high growth rates (>1 % day⁻¹). The growth reduction is attributed to a decrease in feed intake. Fish from the exposed groups displayed an acclimatory response to UIA, as growth rate reduction in these groups, compared to the control, diminished as the experiment progressed, and in the last period, growth rates in the UIA exposed groups was not significantly different from that of the control. Concurrently, a reduction in plasma urea-N content was seen in these groups at the end of the experiment, indicating an increased efflux of urea in response to high ambient UIA.

Poster VI-3

THE EFFECTS OF VARYING LIGHT INTENSITIES ON GROWTH AND SURVIVAL OF ATLANTIC COD (*GADUS MORHUA*) LARVAE.

Jennifer Monk, Velmurugu Puvanendran and Joseph A. Brown
Ocean Sciences Centre, Memorial University, St. John's, Newfoundland, Canada A1C 5S7
E-mail address: Puvy@mun.ca

In recent years Atlantic cod (*Gadus morhua*) has been identified as a species that has much potential for commercial production. Currently one of the major problems encountered with intensive cod production is inconsistent survival and growth rates from hatch through to 'metamorphosis'. The limited success of intensive cod rearing to date is due in part to a poor understanding of the optimal culture conditions required for large scale commercial production. Studies to date have indicated that cod larvae reared under high light intensities perform better than larvae reared under low light intensities up to 28 days post hatch. It has been proposed that a lower light intensity may be ideal during the later larval stages. This study will address the growth, survival and foraging behavior of Atlantic cod larvae reared under varying light conditions in the later larval stages and an ideal lighting regime will be suggested to obtain maximal growth and improve survival of larvae from day zero post hatch to day 60 post hatch. Results indicate that the larvae are significantly longer and heavier and have increased survival rates when light intensity is decreased at 28 days rather than at a later point during development.

Poster VI-4

DIFFERENTIATION OF TISSUES AND ORGANS OF COD LARVAE

Inger-Britt Falk-Petersen
The Norwegian College of Fishery Science, University of Tromsø
E-mail address: ingerf@nfh.uit.no

A presumably immature status of many organs at hatch is a common feature of both gadoids and other species developing via relatively small pelagic eggs and having an extended larval period. The present study illustrates histological and ultramicroscopical details of the organogenesis of cod larvae reared in an enclosure during yolk absorption, first feeding and the transition period from larva to juvenile. The differentiation of cells and tissues of skin, sense organs, digestive organs and body musculature proceeds continuously from hatching throughout metamorphosis. Illustrations of the main organs and organ systems of larvae at various developmental stages after hatch show the main changes taking place in accordance with the gradual improvement of functionality of e.g. vision, smell, taste, digestion and mobility.

Poster VI-5

BEHAVIOURAL AND PHYSIOLOGICAL PROCESSES OF JUVENILE HADDOCK (*MELANOGRAMMUS AEGLEFINUS*) AT CONTINUOUS LIGHT AND NATURAL PHOTOPERIOD

Indra Knauf¹, Edward A. Trippel², Les E. Burrige², Steven R.E. Neil²
¹Leibniz Institute of Marine Sciences at Kiel University, IFM-GEOMAR, Düsternbrooker Weg 20, 24105 Kiel, Germany
²Fisheries and Oceans Canada, St. Andrews Biological Station, 531 Brandy Cove Road, St. Andrews, New Brunswick, E5B 2L9, Canada
E-mail address: iknauf@ifm-geomar.de

Previous research indicated that juvenile haddock (*Melanogrammus aeglefinus*) grow faster at 24 h light compared to natural photoperiod. The objective of this 10-week study was to examine the influence of photoperiod on locomotor activity, food intake, and oxygen consumption on juvenile haddock in order to assess possible factors responsible for the reported differences in body growth. Plasma cortisol levels were measured to examine the relation between photoperiod and stress potential in haddock. 600 juvenile haddock (fork length approximately 12.5 cm, body weight 22.5 g) were randomly distributed and reared in eight 1m² square tanks. The set up was partitioned into three treatments of different photoperiod (natural photoperiod NP, 24 h light, and alternated conditions= 24h-NP-24h). Three trials were conducted to identify possible differences in behaviour. Locomotor activity was recorded daily by counting fish that passed through a fixed station in each tank. Food consumption was measured via counting remaining pellets on the bottom of the tanks. Oxygen consumption was estimated by following the decrease of saturation in each tank over a 1 hour period in static water conditions. The blood of 200 fish was sampled at different time periods and plasma was stored at -80°C and a radioimmunoassay was conducted. Haddock showed significant differences in locomotor activity between treatments. It was greatest under natural photoperiod, less in tanks that received alternating photoperiods and lowest at 24h light. Lower energy consumption for locomotion may be translated into savings for other metabolic processes like growth. No significant difference was found in oxygen consumption between treatments with values ranging from 0.16-0.27 mg/g/h. Fish exhibited good food utilization efficiency (0.13-0.3) with no significant differences between treatments. Cortisol levels were highly variable with values ranging from 17 to 56 ng/ml maximum independent of treatment. These values are relatively high in comparison to other fish species in either resting or stressed conditions.

Poster VI-6

OPTIMUM PHOTOPERIOD FOR SURVIVAL AND GROWTH OF LARVAL COD (*GADUS MORHUA*)

Lawrence J. Buckley and Edward J. Davies
URI/NOAA CMER Program
Graduate School of Oceanography, South Ferry Road, Narragansett, RI 02835
E-mail address: lbuckley@gso.uri.edu

Controlled experiments were completed with larval cod (*Gadus morhua*) to examine the effects of photoperiod and feeding level on survival and growth. Larvae were reared at 7°C and fed enriched rotifers at two levels. All treatment combinations were run in triplicate. Photoperiod treatments were chosen to span ambient conditions found over the range of larval cod and all experiments included a 24 h continuous light treatment. While feeding treatment affected growth, in no instance was a significant interaction observed between the photoperiod and feeding treatments. With first feeding cod larvae (6 to 27 days post hatch), from eggs spawned in January, the highest survival (43%) was observed at the intermediate photoperiod (14.5 h Light-9.5 h Dark) while photoperiod had no significant effect on final size. A second experiment with older pre-flexion larvae from the same spawn (41 to 55 dph) produced the highest survival (48%) and growth (0.07 d⁻¹) with continuous light. In this experiment, more larvae survived at the intermediate photoperiod (14.5 L-9.5 D) compared to the short photoperiod treatment (11.5 L-12.5 D), but no difference in final size was observed between the two groups. A final experiment was completed with a second group of pre-flexion larvae (42 to 63 dph), produced from eggs spawned in April. The shortest photoperiod used in this experiment was 13 h L-11 h D and photoperiod had no effect on either survival (75%) or growth (0.05 d⁻¹). These data suggest that optimum photoperiod may change with development and growth of cod larvae. At first feeding, an intermediate photoperiod may be preferable to continuous light. With older pre-flexion larvae, continuous light may be optimal for growth and survival.

Poster VI-7

THE EFFECT OF SUPERSATURATED WATER ON GROWTH AND SURVIVAL IN JUVENILE COD

Katrine Skajaa and Hilde Toften
Norwegian Institute of Fisheries and Aquaculture Research, Dept. of Aquaculture, Box 6122, N-9291
Tromsø, Norway
E-mail address: katrine.skajaa@fiskeriforskning.no

Supersaturated water is generally believed to cause decreased survival, growth and health in fish. Farm practice indicates that saturation limits recommended for other species are too high for cod. In the current experiment the effect of gas supersaturation, where the supersaturation was obtained by adding nitrogen gas, was investigated for juvenile cod. Two treatment groups were set up with levels of total gas saturation (TGS) during the first 14 days of approx. 101.5 % and 103 % respectively, before TGS was increased to and kept at approx. 103 % and 105 % until the end of the experiment. The control groups had a TGS of 96 %, and the mean O₂ level in all groups was above 90 % throughout the experiment. Temperature, TGS, O₂ and barometric pressure was monitored in each tank once or twice per day. At day 0, 14, 28 and 51, standard length and weight was measured in individually marked fish, and in addition a minimum of 12 fish from each group were killed and examined for changes in blood parameters (Cortisol, Glucose, Ions, PCO₂, Urea, Hematocrit, pH) and external and internal symptoms of emboli. The levels of TGS tested in the current experiment did not seem to have a negative effect on survival and growth for juvenile cod. Result from the effect on the physiology in the fish will be presented.

Poster VI-9

STUDY OF MALFORMATION AND MORTALITY IN COD EGGS FROM SPAWNING STOCK COLLECTED FROM 4 NORWEGIAN FIORDS (PORSANGER FJORD, TYSFJORD, HELGELAND AND ØYGARDEN).

Valeri Makhotin¹, Valentina H. Foss¹, Ann-Lisbeth Agnalt², Sonnich Meier² and Håkon Otterå².

¹ Department of Ichthyology, Moscow State University, Russia

² Institute of Marine Research, Bergen, Norway

E-mail address: sonnich.meier@imr.no

Basic studies in fish embryology have demonstrated that malformation during embryogenesis occurs spontaneously without any external influence. Malformations appearing during egg and larval development are documented both in experimental and fieldwork. However, in most studies of ichthyoplankton, malformations have been connected to pollution and extreme variations in the physical environment. Only few authors consider egg mortality due to failing to pass critical developmental stages to be of any significance. Laboratory experiments done at the Institute of Marine Research have shown that eggs from first-time spawners cod have a significantly higher mortality than for the same individuals as repeat spawners. Genetic factor (Solemdal, 1997) was shown in two different stocks of cod, coastal cod (Solemdal et al., 1995) and the Arcto-Norwegian cod (Solemdal et al., 1998). Field studies from Lofoten showed that the average natural mortality of the cod eggs from the investigated area was 23.2 %, 31 % and 31.1% in the years 2000 - 2002, respectively (Makhotin & Solemdal, in prep.). The egg mortality was caused by malformations occurring during egg development or during hatching. It is very important to get more insight into the basic causes of this mortality, that can be an extremely important regulatory mechanism for the reproduction success both in the wild cod population and in breeding stocks. In the spring 2004 will we study the natural frequency of malformations in the offspring from 40 cod mating pairs collected from 4 Norwegian fiords (Porsanger fjord, Tysfjord, Helgeland and Øygarden). Furthermore will cross-fertilization experiments be used trying uncover the genetic components of the malformation frequency.

Poster VI-10

FACTORS INFLUENCING TEMPERATURE DEPENDENT DEVELOPMENT RATES OF COD (*GADUS MORHUA* L.) EGGS

Audrey J. Geffen,¹ Clive J. Fox,² and Richard D. M. Nash³

¹Institutt for biologi, Universitetet i Bergen, Bergen, Norway.

²The Centre For Environment, Fisheries and Aquaculture Science, Pakefield Road, Lowestoft, Suffolk, England, NR33 OHT.

³Port Erin Marine Laboratory, School of Biological Sciences, University of Liverpool. Port Erin, Isle of Man, Great Britain, IM9 6JA.

E-mail address: Audrey.Geffen@bio.uib.no

The development rates of Irish Sea cod eggs were determined for temperatures between 6 - 12°C. The development of individual eggs was also monitored. The total duration of the egg stage in our experiments ranged from 15 days at 6 °C to 7 days at 12 °C. We compared our results with those of 8 published studies of temperature development rates in cod larvae, using at least 5 different cod populations, and covering temperatures from -1 to 12°C. Comparisons between studies were difficult because 7 different development staging systems were used by the different authors to define cod embryo development. By synchronising the development stages in use, we were able to directly compare stock differences in influence of temperature on developmental rates. Some effects of egg size have also been noted, with small eggs developing faster at the same temperature.

Poster VII-1

EFFECTS OF WATER MOVEMENT ON SURVIVAL AND GROWTH OF EGGS AND NEWLY HATCHED LARVAE OF COD AND HALIBUT.

1 Ingegjerd Opstad, and 2 Arnt Jan Raae,
1 Institute of Marine Research, Austevoll, N-5392 Storebø, Norway
2 University of Bergen, Department of Molecular Biology, N- 5020 Bergen, Norway"
E-mail address: Ingegjerd.Opstad@imr.no

Farming techniques imply an environmental situation for eggs and larvae that are substantially different from their natural situation in the ocean. In aquaculture the eggs and the larvae are stressed, due to contact with the walls of the rearing tanks, sieves, high density of eggs and larvae, violent water streams, handling, different light regimes and higher number of bacteria and virus. Put together these factors comprise a complex set of factors, which may have serious effects on larval survival, growth and development. The present study was carried out in order to evaluate the effect of stress on halibut and cod eggs and larvae in a rearing situation. One day after fertilisation, the eggs were transferred to 6 l tanks 120 halibut eggs and 350 cod eggs in each. Constant and stable temperature was obtained by emerging the tanks in water bath, and the tanks were covered with plastic plates and kept in darkness. The temperature were $7 + 0,5$ °C, and the salinity were $32 + 1$ ppt. We report the effect of different amounts of turbulence, in the form of air bubbling, on halibut and cod eggs and newly hatched larvae. The effect of stress was measured by mortality, dry weight development of the larval body and yolk sac and the contents of DNA, RNA and soluble protein. Yolk sac utilisation was calculated.

Poster VII-2

USE OF CONTINUOUS LIGHT TO DELAY PUBERTY IN FARMED ATLANTIC COD

Cathrine Kristoffersen 1, 2, Ørjan Karlsen 1, Rüdiger W. Schulz 1,3, Herve Migaud 4, Sigurd Stefansson 2 and Geir Lasse Taranger 1
1 Institute of Marine Research, Norway
2 University of Bergen, Norway
3 University of Utrecht, The Netherlands
4 University of Stirling, UK
E-mail address: cathrine.kristoffersen@imr.no

Early puberty is a major problem in farming of cod. Spawning imposes problems with arrested growth, altered harvest quality and a longer production cycle. The present study tested effects of continuous light (LL) with different intensities outdoors compared to LL indoors or natural light (NL) on age at puberty and testis development in cod. Atlantic cod were first fed in a seawater pond in Flødevigen, Arendal during spring 2001. From July 2002, they were held in 3 m circular seawater tanks at Austevoll Aquaculture Research Station and exposed to four different light regimes in duplicate tanks until February 2004:

1. NL: Natural light (60°N).
2. LL: Fully covered tanks with continuous light of low intensity (~300 lux).
3. NL+LI: NL + continuous light of low intensity (~300 lux).
4. NL+HI: NL + continuous light of high intensity (~900 lux).

Sexually maturing fish was scored by visual examination of gonads and gonadosomatic index at regular intervals during the experiment. Testis development was analysed by histology in January, March and June 2003. Diel blood samples were obtained from the groups in January, March and June 2003 for determination of plasma melatonin. In January 2003, 43% of the males in the NL group were scored as maturing. There were no maturing males in the LL and the NL+HI groups at this time, whereas the NL+LI group had 10% sexual maturing males. Histological examination showed that the lowered proportion of sexually maturing fish in the light treated groups was accompanied by arrested spermatogenesis (early or late spermatogonia) in most males, and an increased occurrence of germ cell apoptosis (early spermatocytes or spermatids). The NL+HI treatment completely inhibited the normal night time increase in plasma melatonin. It seems that the NL+HI treatment was equally effective as the LL treatment in arresting sexual development.

Poster VII-3

EFFECTS OF REPLACING FISH MEAL WITH TWO VEGETABLE PROTEIN RESOURCES (SOYBEAN AND CORN GLUTEN MEAL) IN DIETS FOR ATLANTIC COD (*GADUS MORHUA*).

Ann-Cecilie Hansen¹, Kristoffer Tveit², Grethe Rosenlund², Ørjan Karlsen³, Gro-Ingunn Hemre¹
1 National Institute of Nutrition and Seafood Research (NIFES), Bergen, Norway
2 Nutreco ARC, Stavanger, Norway
3 Institute of Marine Research, Austevoll, Norway
E-mail address: ahan@nifes.no

Diets for the strict carnivorous Atlantic cod have so far been based on high protein levels and quality, necessary to obtain high growth rates, efficient utilisation of the protein and good fish health. To use only high-quality fish meal and oil in diets to cod will not be sustainable in future, due to high costs and expected production increases. Using earlier findings on recommended balance between protein, lipid and starch, a trial was set up to elucidate the effect of replacing fish meal by fat-extracted soybean meal, corn gluten meal or a mixture of these, in a regression design, using iso-nitrogenous and iso-caloric diets. Growth and feed utilisation were affected by increases in vegetable protein, and where corn gluten exerted the major effect. Soybean influenced production results to a minor extent when limiting addition to below 20% of diet dry matter. More details on this, feed utilisation, retention of nutrients and fish health will be presented.

Poster VII-4

NEW NET PEN TECHNOLOGY TO PREVENT ESCAPE OF COD IN THE ON-GROWING PHASE.

Heidi Moe, Arne Fredheim, Mats A. Heide and Leif Magne Sunde
SINTEF Fisheries and Aquaculture
E-mail address: Heidi.Moe@Sintef.no

Escape of cod has become a major problem in sea-based fish farming. Large amounts of cod escapes even from high quality fish cages. In addition to possible environmental impact, the escape of farmed cod has economical consequences for the fish farmers. Thus, to prevent fish from escaping the net pen, is one of the most crucial success-factors in order to assure a profitable cod fish farming industry in the future. In Norway, cod fish farming is a new and promising industry. Most of the aquaculture fish farms still have their first generation of cod in the net pens. The cod is produced in small numbers and in small size cages. However, the trend is towards larger cages, which may increase the number of escaped cod. The behaviour of cod is different from the behaviour of salmon. The cod seem to be eager to escape and search for holes in the net pen. The experience with salmon is that they need relatively large holes in order to escape, while significant amounts of cod can escape through a small hole in a short amount of time. It is also a common opinion among cod fish farmers that the cod nibble at the net pen and create escape holes. Most cod farmers use standard open sea fish farming technology and equipment. However, several farmers have concluded that standard net pens are not suitable for cod farming. We see the need of a common focus towards new and specialized net pen technology for cod farming. It is of vital importance that this problem is dealt with in the nearest future, while cod aquaculture still is in the initialisation phase and prior to large investments in aquaculture technology. SINTEF Fisheries and Aquaculture has an ongoing project that focus on new technology to prevent escape of salmon and has initiated similar activities related to farmed cod. Important topics are net pen construction, materials and operation.

COD AND HADDOCK PRODUCTION IN SUBMERGED CAGES OFF THE COAST OF NEW HAMPSHIRE, USA

W.H. Howell and M. J. Chambers
Dept. of Zoology, University of New Hampshire, Durham, NH 03824
E-mail address: whh@cisunix.unh.edu

The University of New Hampshire's Open Ocean Aquaculture Project seeks to stimulate the development of offshore aquaculture in the northeastern United States. As part of this project, both cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) are being raised in submerged cages at an exposed location 15km off the coast of New Hampshire, USA.

Thirty thousand 3-4g cod, produced by Great Bay Aquaculture, LLC, were transferred from the hatchery into four 35m³ inshore net pens in April 2003. In September 2003, when mean size was 45g, most of the fish were transferred offshore into a 200m³ nursery net located inside a 3000m³ Sea Station cage, located 12 meters below the surface. Approximately 600 fish were left in the inshore net pen so that we can compare their growth and survival to those in the offshore cage. Offshore fish were released into the main cage in mid-November when mean weight was approximately 90g, and will be grown to market size (2-3kg). Some of the fish were equipped with small ultrasonic transmitters, and the cage has been equipped with an array of instruments, including hydrophones, video cameras, temperature/light intensity data loggers, and a current meter. Data currently being collected will allow us to study fish behavior, activity and physiology, and how these are affected by environmental conditions. Information on cod growth, survival, FCR, behavior and activity will be presented.

Our haddock work has been done in collaboration with Heritage Salmon Limited, New Brunswick, Canada, and the objective is to study the performance of haddock in offshore net pens. The project began in mid-September 2002, when a total of 3000 haddock (16 g mean weight), produced at the National Research Council Laboratory in Halifax, Nova Scotia, Canada, were transferred to a 35m³ inshore nursery pen New Hampshire, USA. By mid-December 2002 their mean size had increased to 78g, and the fish were transferred to one of our offshore cages in mid-December 2002. Growth and survival have been monitored, and our intention is to leave the fish in the offshore cage until they reach market size (2-3kg). Growth performance and survival in the submerged, offshore cage will be reported.

Poster VIII-1

DYNAMICS OF MATURATION AND SPAWNING OF NORTHEAST ARCTIC COD, *GADUS MORHUA*, IN SEA CAGES AT THE BARENTS SEA COAST OF RUSSIA

Valentina Anokhina

Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Street, Murmansk,
E-mail address: inter@pinro.ru

World tendency to expand cultivation of the Northeast Arctic cod (*Gadus morhua*) encourages national research into biology of this species. An in-depth study of physiological reaction of fish organisms to environmental variation seems to be necessary for the objective evaluation of ecological potential and flexibility of the species and allows predicting and managing the cod life cycle under controlled conditions. The objective of the research is to study peculiarities of maturation and spawning dynamics of the cod breeders in sea cages in the Barents Sea. The research was conducted at the experimental research station of PINRO in the Ura Guba at the Barents Sea coast of Russia. The object of the research were individuals of wild Northeast Arctic cod of different age which were caught in the Motovsky Bay in the southern Barents Sea, delivered to the experimental research station and reared in the salmon sea cages for more than a year. The cod was aged by otoliths. Status of reproductive system and gametogenesis were studied from histological preparations. Maturity stages were identified and gonadosomatic index was determined. Spawning dynamics of males and females was controlled. Eggs were fertilized artificially and incubated under natural habitat. Totally 168 individuals of the cod juveniles and breeders were analysed. The cod examined was from 3 to 7 years old. The selected group of breeders constituted 41 % of total number of the reared cod. Percentage of individuals with running gonads was 58% of the cod examined. No anomalies in gametogenesis were observed. Quantity of heat required to complete maturation took 1280 degree-days (from planting into sea cages in May to getting the first portions of eggs in cod females of older age in April next year). A shift of the spawning season in some males and females was found to be synchronous with plankton development. In these breeders the peak of spawning occurred in the second half of May – beginning of June. Distinct differentiation of periods when cod of different age enter the completion phase of spawning was ascertained. The eggs fertilized artificially developed without visible anomalies. Generative system of the Northeast Arctic cod is extremely flexible. The wild cod mature normally, spawn and produce high-grade gonads in sea cages at the Barents Sea coast of Russia.

Poster VIII-2

COD (*GADUS MORHUA KILDENSIS* DERJUGIN) FROM THE MOGILNOE LAKE: LIFE CYCLE AND LIVING CONDITIONS. APPLICATION TO MARICULTURE

Oleg Titov¹, Nina Mukhina¹

¹ Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Street, Murmansk, 183763 Russia

E-mail address: inter@pinro.ru

The Mogilnoe Lake is located in the southeastern extremity of the Kildin Island, in the Barents Sea. It is not large in size and characterized by the availability of fresh and seawater layers with the population, which is typical for them, constant stratification of water column and a considerable body of hydrogen sulphide in bottom layers. Forming unique, partially enclosed ecosystem of the lake favoured evolutionary changes of marine organisms occurring there and the appearance of special cod subspecies *Gadus morhua kildinensis* Derjugin dwelling in this water reservoir. The life of this species passes in the specific conditions characterized by limited specific variety of marine organisms, the lack of predators and fishing press, and a very poor ration. The cod spend the most part of life in the salt layer with a low oxygen content, but quite a lot of time – in the fresh water. It makes the life of the Kildin cod to be the same as of the lake species. A short cycle, low fatness, rapid growth rate of immature individuals is peculiar to this fish. The Mogilnoe Lake has been studied already for more than 100 years. In 1997-2000, the investigations were carried out by Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO). They involved a wide complex of hydrological, biohydrochemical, hydrobiological, microbiological, parasitological and ichthyological researches. The data from the investigations were interesting for specialists engaging in cod culture. In contradistinction to oceanic cod, the Kildin cod has a number of adaptative peculiarities, which, probably, might increase the efficiency of rearing in the fishing farms. And the Mogilnoe Lake may be considered as a model of closed and quite efficient ecosystem providing cod reproduction in the limited area.

Poster VIII-3

CRYOPRESERVATION AND COMPUTER-ASSISTED MOTILITY ASSESSMENT OF ATLANTIC COD (*GADUS MORHUA*) SPERMATOZOA

J.Dana DeGraaf¹, Nancy G. Smith² and David L. Berlinsky¹
1 Department of Zoology, University of New Hampshire, Durham, NH 03824, USA
2 Hamilton Thorne Biosciences, Inc., Beverly, MA 01915, USA
E-mail address: David.berlinsky@unh.edu

Sperm preservation has been used in hatcheries to facilitate artificial propagation and genetic improvement, minimize the cost of maintaining broodstock, and reduce the risk of disease transmission (Cloud et al., 1990). The goals of this study were to improve methods for short and long-term preservation of Atlantic cod (*Gadus morhua*) spermatozoa and use computer-assisted sperm analysis (Hamilton Thorne Biosciences CEROS® V12.2g; CASA) and differential fluorescent staining (propidium iodide/SYBR 14®) to assess post-thaw viability and motility. The effects of extender composition, cryoprotectant concentration, freezing rate, and dilution ratio on post-thaw sperm motility were examined and the fertilization capacities of fresh and post-thaw sperm were compared. The highest post-thaw motility was obtained when sperm was diluted 1:3 with an extender containing glutathione, sucrose and potassium bicarbonate (Mounib's modified extender, MME), supplemented with 10% DMSO and frozen at a rate of $-5^{\circ}\text{C min}^{-1}$ (64%). The post-thaw motility of cod sperm was not different after 5 (64%) or 90 (63%) days of storage but was lower than fresh sperm (83%). No difference in fertilization rate was found between fresh (71%) and post-thaw sperm (69%). Observed spermatozoa motility was highly correlated (Adjusted $R^2 = 0.94$) with the proportion of cells that incorporated SYBR 14® but all measurements of velocity and linear motility, as measured by CASA, were significantly lower for post-thaw sperm than fresh. Refrigerated cod sperm diluted 1:3 with MME remained motile for up to 40 days. These results demonstrate the feasibility of obtaining high fertilization rates using cryopreserved cod sperm for hatchery production.

Reference: Cloud, J.C., Miller, W.H., Levanduski, M.J., 1990. Cryopreservation of sperm as a means to store salmonid germ plasma and to transfer genes from wild fish to hatchery populations. *Prog. Fish-Cult.* 52, 51-53.

Posters VIII-4

THE DEVELOPMENT OF HADDOCK AND ATLANTIC COD SPERM CRYOPRESERVATION TECHNIQUES AND THE EFFECT OF SPERM AGE ON CRYOPRESERVATION SUCCESS

Rick M. Rideout^{1,2}, Edward A. Trippel¹ and Matthew K. Litvak²
1 Fisheries and Oceans Canada, Biological Station, 531 Brandy Cover Rd., St. Andrews, NB, E5B 2L9, Canada
2 Department of Biology and Centre for Coastal Studies and Aquaculture, University of New Brunswick, Saint John, NB, E2L 4L5, Canada
E-mail address: trippele@mar.dfo-mpo.gc.ca

Three cryoprotectants (dimethyl sulphoxide, propylene glycol, glycerol), two diluents (sucrose-based, saline-based), two sperm collection times, two freezing rates and three times between thaw and activation (0, 30, 60 min) were tested in order to develop a protocol for the cryopreservation of sperm of haddock, *Melanogrammus aeglefinus*, and Atlantic cod, *Gadus morhua*. The faster freezing rate resulted in extremely low post-thaw motility in comparison to the slower freezing rate, which was successful for sperm from both gadids. In both cases, the use of propylene glycol (PG) resulted in significantly higher post-thaw sperm motility-recovery indices than with dimethyl sulphoxide (DMSO) or glycerol, which did not differ significantly from one another. Diluent had no effect on post-thaw sperm motility for cod or haddock. Sperm collected at the end of the spawning season tended to have reduced post-thaw motility compared to that collected two weeks after the start of spawning. A 30-min delay between thaw and activation of haddock and cod sperm resulted in a significant decrease in sperm motility. When PG was used as a cryoprotectant, sperm motility continued to decrease between 30 and 60 min post-thaw and did not decrease any further after 60 min. Cryoprotectant, diluent and time between thaw and activation had no effect on mean or maximum sperm swimming speeds for either cod or haddock sperm. Fertilization success for haddock eggs, like sperm motility, was higher with PG frozen sperm than DMSO or glycerol frozen sperm. These results constitute the first reported successful cryopreservation of haddock sperm and improve on previous methods used to cryopreserve sperm from Atlantic cod.

RESULTS OF PRELIMINARY STUDIES ON THE TAXONOMICAL STATUS OF COD STOCKS IN THE SOUTHWESTERN BALTIC AT POLISH COASTS

Beata Wiececzek¹ and Artur Antoszek²

Faculty of Food Sciences and Fisheries, University of Agriculture, Szczecin, Poland

^{1,2}: Dep. of Fish Systematics

E-mail address: wienca@fish.ar.szczecin.pl

In the Baltic Sea there are considered to be two cod populations or stocks, which have been shown to differ from each other by some morphometric and meristic characters, haemoglobin types, otolith structure and allele- frequencies of loci coding some enzymes. The western Baltic cod stock *Gadus morhua morhua*- the transition area cod is distributed west from the Bornholm Island, the eastern one *G. morhua callarias*- the Baltic Sea cod – east from the Bornholm Island area. The border between these two main stocks is diffuse and mixing of stocks is evident in the Arkona Basin and the Bornholm Basin (Bagge et al. 1994) The samples of cod for investigation were captured in the southwestern Baltic Sea – at the fishing ground Odrzanskie (ICES SD 24 , 54°08'N, 14°50'E, at the depth of 9-10 m, in April, 1998, n=60) and the fishing ground Kolobrzieszko-Darłowskie (SD 25, 54°31'N, 15°02'E, at the depth of 41 m, in March, 2002, n=50). Two sampling areas in the Baltic are situated in different ICES Sub-divisions, nevertheless they are very close to each other. The detailed analysis involved 9 meristic characters and 35 metric ones, with regard to sex and age. Total length of cod from the fishing ground Odrzanskie covered the range 30.2-44.4 cm (mean value- 38.05; males were longer than females), while from Kolobrzieszko-Darłowskie -29.5-48.3 (average- 38.1 cm, females were longer). Two samples from the Baltic fishing grounds differed statistically in the vertebral count and number of rays in the first and second anal fins (Scheffe's test in one- way analysis of variance ANOVA). Distance matrices of samples were clustered by single linkage method; fishes from two locations under investigation differed stronger while compared to samples from 2 sites in Atlantic (in the Barents Sea and Irminger's Sea). Metric characters differed statistically in case of seven features (related to TI) and five characters of head (related to head length). Genetic studies (performed on 10 individuals from each sample, mt-DNA, PCR-RFLP method) showed no differences between populations investigated. Adult Baltic cod can live and survive even in salinities lower than 5 per mille, juveniles are able to tolerate an almost freshwater environment over long periods, however the adaptation process into the Baltic Sea is not complete. This is clearly observed in Baltic cod reproduction strategy and its adaptations in terms of egg buoyancy (Aro 2000). It can be concluded that the collapse of cod resources in Baltic Sea makes the stocking with juveniles or mariculture (although the Polish coast line is not suitable for this purpose) to be taken into account in the nearest future. In order to realize this aim without any severe biological complications, the taxonomical status of Baltic cod should be estimated precisely, based on biometric, osteological and biological features of this species.

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Posters VIII-6

STEROID SYNTHESIS IN OVARIAN TISSUE OF ATLANTIC COD IN VITRO

Helge Tveiten¹ and Marianne Frantzen²

¹ Norwegian Institute of Fisheries and Aquaculture Research, Tromsø, Norway;

² Norwegian College of Fishery Science, University of Tromsø, Tromsø, Norway

E-mail address: helge.tveiten@fiskeriforskning.no

There is limited information about the endocrine regulation of final stages of oocyte maturation in the Atlantic cod (*Gadus morhua*). In order to get information about steroids that may be involved in this process, ovarian tissue was incubated with tritiated steroid precursors in vitro. Ovarian follicles from late vitellogenic Atlantic cod were incubated at 6°C in medium 199 for about 18h with either tritiated 17-hydroxyprogesterone (17-P) or 17,20b-dihydroxy-4-pregnen-3-one (17,20b-P) as steroid precursors. Incubation products were extracted on C18 Sep-Pak columns and separated on thin layer chromatography (TLC) with "cold" standards as reference. Several structurally related C21 steroids and human chorionic gonadotropin (hCG), were tested for their ability to induce GVBD. Oocytes were incubated for several days as indicated above. Follicles actively metabolised 17-P, and fractionation of the incubation products revealed that about 50% of the activity appeared as free and conjugated steroids, respectively. Separation of the free steroids by TLC revealed that most of the radioactivity appeared in two, yet unidentified, peaks. Their migration pattern, indicate, however, that they contain at least two hydroxyl groups. A combination of acid solvolysis and glucuronidase ("snail juice") treatment indicates that only one of the two steroids is being conjugated, and that most of the conjugate is a sulphated steroid. When 17,20b-P was used as the precursor about 65% of the radioactivity appeared as conjugates of which most (80%) was identified as 17,20b-P sulphate.

Poster VIII-7

ANTIOXIDANTS IN COD ROE OF WILD ORIGIN FROM BALTIC AND WESTERN POPULATIONS

Jana Pickova, Swedish University of Agricultural Sciences, Department of Food Science; Uppsala, Sweden

E-mail address: jana.pickova@lmv.slu.se

The reproductive success of Baltic cod has been discussed in terms of lower hatching rates and survival than for western cod stocks. We have investigated the fatty acid profiles of the two different populations. An increased amount of long chain polyunsaturated fatty acids (LCPUFA) was found in Baltic eggs compared to the eggs of Skagerrak origin. It is known that LCPUFA are more prone to peroxidation than other fatty acids. Therefore we have investigated the level of some lipid soluble antioxidants in the roe of these two populations. This to conclude if the antioxidant level increases as the unsaturation increases. Results on astaxanthin and total carotenoids so far indicate that there is a negative correlation between the LCPUFA and carotenoids. The values of astaxanthin found were for the Baltic cod 0.29 (n=6; SD = 0.14) and for the Skagerrak cod 0.48 (n=6; SD=0.16). These results make it necessary to perform more analytical work to be able to conclude how these contradicting trends in the content of LCPUFA and antioxidants are related to each other. Therefore, we suggest that measurements on retinol and tocopherols should also be performed. To be able to explain the obtained results, we hypothesise that the low antioxidant level will trigger a feed back mechanism to increase the elongation and desaturation enzymes to compensate for the risk of peroxidation. A similar mechanism was suggested by other studies on salmon muscle and in a study on salmon eggs. These results may be of large importance for the egg quality when farming activities will be started on Baltic cod. The wild parental fish from the Baltic stock will probably have to be supplemented by antioxidant rich diet prior spawning.

Poster VIII-8

INFLUENCE OF MATERNAL EFFECTS ON COD INFERRED BY THE OTOLITH MICROSTRUCTURE ANALYSIS

Vivian Buehler¹, Gary Carvalho², Richard Case², Catriona Clemmesen¹, Lorenz Hauser², William F. Hutchinson², Olav Sigurd Kjesbu³, Erlend Moksness³, Haakon Otteraa³, Helge Paulsen⁴, Anders Thorsen³ and Terje Svaasand³

¹ Leibniz Institute for Marine Sciences, DE

² University of Hull, UK

³ Institute of Marine Research

⁴ DIFRES, DK

E-mail address: vbuehler@ifm.uni-kiel.de

Maternal effects are known to influence propagule size, and consequently their offspring fitness. In this study, offspring from first and repeat spawners were submitted to the same environmental conditions in two large mesocosms (2500m³ and 4400m³), during a period of ten weeks. In addition to egg size and egg quality measures, larval length and weight were recorded for the different rearing periods in the mesocosms. Based on DNA fingerprinting, the parental origin was assigned back to each single cod larva sampled in the mesocosms, and condition was estimated by the RNA/DNA ratio method. Finally, the otolith microstructure analysis permitted to follow growth trajectories and determine the characteristics of survivors. Female size was positively correlated to egg size and energy content whilst otolith hatch check width was positively correlated to egg size and larval condition. Finally, individuals that were small or large at hatching maintained this trend until the end of the experiment

Poster VIII-9

SPAWNING CYCLE OF CAPTIVE COD FROM FOUR REGIONS IN NORWAY

Håkon Otterå, Ann-Lisbeth Agnalt, Knut Jørstad

Institute of Marine Research, Bergen, Norway

E-mail address: haakon.otteraa@imr.no

During the natural spawning season of 2003 and 2004, 40 couples of Atlantic cod were placed in individual spawning tanks. Their spawning success in terms of amount spawned, egg quality and egg diameter were monitored on a daily basis. The families originated from four different regions along the Norwegian coast (only three for 2003 experiment), with quite different natural temperature and light regimes. The broodstock were collected one and two years respectively before the spawning experiments, and transported to Parisvatnet outside Bergen, Norway where they were kept in cages until the experiments. During this period they were fed formulated feed, and all experienced the same environment. Thus, differences in spawning performance, especially for the last year, should partly reflect genetical differences between groups. The fecundity and spawning cycle will be discussed in view of origin as well as phenotypical characteristics of the broodstock.

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